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REPORT
OF THE
SEVENTY-SIXTH MEETING OF THE
BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE



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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.

Subscriptions shall be received by the Treasurer or Secretaries.

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.]

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 2s. 6d. 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.

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 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 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.

Constitution of the Sectional Committees.³

(i) The President, Vice-Presidents, and Secretaries of a Section are appointed by the Council in November or December. They form, with the existing members (see (ii) and (vi)), the Committee, which has the duty of obtaining information upon the Memoirs and Reports likely to be submitted to the Section at the next meeting, of preparing a report thereon, of generally organising the business of the Section, and of bringing before the Council any points which they think deserving of consideration.⁴

¹ Revised by the General Committee, Liverpool, 1896.

² Revised, Montreal, 1884.

³ Adopted by the General Committee at Cambridge, 1904.

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

(ii) The Sectional Presidents of former years are *ex-officio* members of these Committees.

(iii) The Sectional Committees may hold such meetings as they think proper for the organisation of the business, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting at 2 P.M. for the appointment of additional Members and other business.

Any member who has served on the Committee in previous years, and who has intimated his intention of being present at the Meeting, is eligible for election as a Member of the Committee at its first meeting.

(iv) The Sectional Committees shall have power to add to their number from day to day during the Annual Meeting, but it is not desirable for them to be larger than is necessary for efficiency ; they have also the power to elect not more than three Vice-Presidents at any time during the meeting, in addition to those appointed by the Council.

(v) The List formed during the Annual Meeting 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.

(vi) Before the close of the Annual Meeting each Sectional Committee is to nominate six members of the Association to form the nucleus of the Committee for the succeeding year, and forward a list of the six names to the Assistant Secretary of the Association.

Included in the six names should be the existing President of the Section, or one of the Vice-Presidents, and one of the existing Secretaries.

It will be the duty of these Members to transact the business of the Committee until the officers of the Section for the ensuing year are appointed by the Council, and thus become the officers of the Committee (see (i)).

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday, and on the following Thursday, Friday, Saturday (optional), Monday, and Tuesday, for the objects stated in the Rules of the Association. The Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee.

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

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

they are to be read, are now as far as possible determined by the Sectional Committees *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 Secretary *before the conclusion of the Meeting*.

and printed in the last volume of the Report. He will next proceed to read the Report of the Committee that has held office since the last Annual Meeting. No paper shall be read until it has been formally accepted by the Committee of the Section, and entered on the minutes accordingly. 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 prepare a copy of the Journal for the following day by (i) removing from the list of papers those which have been read on that day; (ii) making any needful additions to or corrections in the list of those appointed to be read on following days; (iii) revising the list of the Sectional Committee, and making any other necessary corrections, 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 at each Meeting of the Committee are to be entered in the Minute-Book, and these Minutes 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 Secretary of the Association.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee, 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 Annual 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 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.

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.

A tabular list of the Committees appointed on the recommendation of each Section shall be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether or no the several Committees appointed on the recommendation of their respective Sections have presented their reports.

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 shall be then fixed, but the Members to serve on such Committee shall be nominated and selected by the Sectional Committee at a subsequent meeting.

Committees have power to add to their number persons, being Members of the Association, whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered on the forms furnished to their Secretaries, and one copy of each is to be forwarded, without delay, to the Assistant Secretary of the Association 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.¹

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.
5. In each Committee the Chairman is the only person entitled to call on the Treasurer, Professor John Perry, 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.

¹ Revised by the General Committee at Ipswich, 1895.

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 any description are requested to reserve the specimens so obtained to be dealt with by authority of the Council.
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.

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.

¹ The Sectional Committee is empowered to arrange the hours of meeting of the Section and of the Sectional Committee, except for Saturday

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 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 Official 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 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 shall not be 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 Secretary.²

*Corresponding Societies.*³

1. (i) Any Society which undertakes local scientific investigation and publishes the results may become a Society *affiliated* to the British Association.

(ii) The Delegates of such Societies, who must be or become members of the British Association, shall be *ex officio* members of the General Committee.

¹ Passed by the General Committee at Birmingham, 1865.

² Passed by the General Committee at Leeds, 1890.

³ Passed by the General Committee, 1884 ; revised 1903, 1905.

(iii) Any Society formed for the purpose of encouraging the study of science, which has existed for three years and numbers not fewer than fifty members, may become a Society *associated* with the British Association.

(iv) Each associated Society shall have the right to appoint a Delegate to attend the Annual Conference, and such Delegates shall be members or associates of the British Association, and shall have all the rights of those appointed by the affiliated Societies, except that of membership of the General Committee.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to the Assistant 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 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.

Conference of Delegates of Corresponding Societies.

6. 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.

7. 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.

8. 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.

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

10. 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.

The Council shall appoint and have power to dismiss such paid officers as they may consider necessary to carry on the work of the Association, on such terms as they may from time to time determine.¹

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 ²

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 and General Secretaries and past Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting
7. Ordinary Members.

¹ Passed by the General Committee at Cambridge, 1904.

² Passed by the General Committee at Belfast, 1874; amended at Cambridge, 1904

- (2) The Ordinary Members shall be elected annually from the General Committee.
- (3) There shall be not more than twenty-five Ordinary Members, of whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.
- (4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year—observing (as nearly as possible) the proportion of three by seniority to two by least attendance.
- (5) The Council shall submit to the General Committee in their Annual Report the names of twenty-three Members of the General Committee whom they recommend for election as Members of Council.
 - (i) A nomination for either of the two vacant seats on the Council may be made in writing by any two or more members of the General Committee, and must be sent to the Assistant Secretary so as to be received by him at least twenty-four hours before the meeting of the General Committee at which the election takes place.
 - (ii) The nominations shall be read to the meeting by the Chairman; and if more than two persons be nominated, the election shall be by ballot or show of hands, and the two having the highest numbers of votes shall be declared elected.
 - (iii) In case no nomination, or only one nomination, shall be received, as provided for by by-law, two seats on the Council (or one seat, as the case may be) shall remain vacant until the next ensuing Meeting of the Council, when the seats (or seat, as the case may be) shall be filled by co-optation of the other members of the Council.¹
- (6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

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

Accounts.

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

¹ Passed by the General Committee at Cambridge, 1904; revised in South Africa, 1905.

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

PRESIDENTS.

The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. }
York, September 27, 1831.

The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. }
Oxford, June 19, 1832.

The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. }
Cambridge, June 25, 1833.

SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., }
F.R.S., F.R.S.E. }
Edinburgh, September 8, 1834.

The REV. PROVOST LLOYD, LL.D. }
Dublin, August 10, 1835.

The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. }
Bristol, August 22, 1836.

The EARL OF BURLINGTON, F.R.S., F.G.S., Chan- }
cellor of the University of London }
Liverpool, September 11, 1837.

The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. }
Newcastle-on-Tyne, August 20, 1838.

The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. }
Birmingham, August 26, 1839.

VICE-PRESIDENTS.

Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S. }
.....

{ Sir David Brewster, F.R.S., F.R.S.E., &c. }
{ Rev. W. Whewell, F.R.S., Pres. Geol. Soc. }
.....

{ G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. }
{ John Dalton, Esq., D.C.L., F.R.S. }
.....

{ Sir David Brewster, F.R.S., &c. }
{ Rev. T. R. Robinson, D.D. }
.....

{ Viscount Oxmantown, F.R.S., F.R.A.S. }
{ Rev. W. Whewell, F.R.S., &c. }
.....

{ The Marquis of Northampton, F.R.S. }
{ Rev. W. D. Conybeare, F.R.S., F.G.S. }
J. C. Pritchard, Esq., M.D., F.R.S. }
.....

{ The Bishop of Norwich, P.L.S., F.G.S. }
{ Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. }
{ Rev. W. Whewell, F.R.S. }
.....

{ 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. }
.....

{ The Marquis of Northampton. }
{ The Rev. F. R. Robinson, D.D. }
{ The Very Rev. Principal Macfarlane }
.....

LOCAL SECRETARIES.

{ William Gray, jun., Esq., F.G.S. }
{ Professor Phillips, M.A., F.R.S., F.G.S. }
.....

{ Professor Daubeny, M.D., F.R.S., &c. }
{ Rev. Professor Powell, M.A., F.R.S., &c. }
.....

{ Rev. Professor Henslow, M.A., F.L.S., }
F.G.S. }
{ Rev. W. Whewell, F.R.S. }
.....

{ Professor Forbes, F.R.S., F.R.S.E., &c. }
{ Sir John Robinson, Sec. R.S.E. }
.....

{ Sir W. R. Hamilton, Astron. Royal of }
Ireland, &c. }
{ Rev. Professor Lloyd, F.R.S. }
.....

{ Professor Daubeny, M.D., F.R.S., &c. }
{ V. F. Hovenden, Esq. }
.....

{ Professor Traill, M.D. }
{ Wm. Wallace Currie, Esq. }
{ Joseph N. Walker, Esq., Pres. Royal Insti- }
tution Liverpool. }
.....

{ John Adamson, Esq., F.L.S., &c. }
{ Wm. Hutton, Esq., F.G.S. }
{ Professor Johnston, M.A., F.R.S. }
.....

{ 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.
- The REV. PROFESSOR WHEWELL, F.R.S., &c.
 PLYMOUTH, July 29, 1841.
- The LORD FRANCIS EGERTON, F.G.S.
 MANCHESTER, June 23, 1842.
- The EARL OF ROSSE, F.R.S.
 CORK, August 17, 1843.
- The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S.
 YORK, September 26, 1844.
- SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c.
 CAMBRIDGE, June 19, 1846.
- SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S.
 SOUTHAMPTON, September 10, 1846.
- SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S.,
 M.P. for the University of Oxford.
 OXFORD, June 23, 1847.
- { 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-Edgumbe }
 { Andrew Liddell, Esq.
 Rev. J. P. Nicol, LL.D.
 John Strang, Esq. }
- { The Earl of Morley. Lord Elliot, 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. }
- { 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 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. }
- { 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 Hatfield, Esq., F.G.S.
 Thomas Meynell, Esq., F.L.S.
 Rev. W. Scoresby, LL.D., F.R.S.
 William West, Esq. }
- { 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. }
- { 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. }
- { 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.

The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.

The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.

SIR DAVID BREWSTER, K.H., LL.D., F.R.S., F.R.S.E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 21, 1850.

GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851.

COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society. BELFAST, September 1, 1852.

WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society. HULL, September 7, 1853.

The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.

VICE-PRESIDENTS.

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

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.

The Right Hon. the Lord Provost of Edinburgh
 The Earl of Cabchart, 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.

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. Middleton, Bart.
 J. C. Jobbold, Esq., M.P. T. B. Western, Esq.

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.

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. Licut.-Col. Sykes, F.R.S.
 Professor Wheatstone, F.R.S.

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., F.R.S.E., F.R.A.S.
 Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.

LOCAL SECRETARIES.

Matthew Moggridge, Esq.
 D. Nicol, Esq., M.D.

Captain Tindal, R.N.
 William Willis, Esq.
 Bell Fletcher, Esq., M.D.
 James Chance, Esq.

Rev. Professor Kelland, M.A., F.R.S., F.R.S.E.
 Professor Balfour, M.D., F.R.S.E., F.L.S.
 James Tod, Esq., F.R.S.E.

Charles May, Esq., F.R.A.S.
 Dillwyn Sims, Esq.
 George Arthur Biddell, Esq.
 George Ransome, Esq., F.L.S.

W. J. C. Allen, Esq.
 William M'Gee, Esq., M.D.
 Professor W. P. Wilson.

Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society.
 Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.

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, 1856.

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 REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S.,
F.R.S.E., V.P.R.I.A.
DUBLIN, August 26, 1867.

RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S.,
F.G.S., Superintendent of the Natural History Depart-
ments of the British Museum.
LEEDS, September 22 1858.

HIS ROYAL HIGHNESS THE PRINCE CONSORT..
ABERDEEN, September 14, 1859.

THE LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. . . .
Oxford, June 27, 1860.

{ 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., F.R.S.E. Walker 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.

{ 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.

{ 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.

{ 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.

{ 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. Henschel, Bart., M.A., D.O.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

{ 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 Oxford-
shire
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.

{ John Strang, Esq., LL.D.
Professor Thomas Anderson, M.D.
William Gourlie, Esq.

{ Capt. Robinson, R.A.
Richard Beamish, Esq., F.R.S.
John West Huggell, Esq.

{ Lundy E. Foote, Esq.
Rev. Professor Jellett, F.T.C.D.
W. Neilson Hancock, Esq., LL.D.

{ Rev. Thomas Hincks, B.A.
W. Sykes Ward, Esq., F.C.S.
Thomas Wilson, Esq., M.A.

{ Professor J. Nicol, F.R.S.E., F.G.S.
Professor Fuller, M.A.
John F. White, Esq.

{ George Rolleston, Esq., M.D., F.L.S.
H. J. S. Smith, Esq., M.A., F.O.S.
George Griffith, Esq., M.A., F.C.S.

PRESIDENTS.

WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S.
MANCHESTER, September 4, 1861.

The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor
of Natural and Experimental Philosophy in the Univer-
sity of Cambridge
CAMBRIDGE, October 1, 1862.

SIR W. ARMSTRONG, C.B., LL.D., F.R.S.
NEWCASTLE-ON-TYNE, August 26, 1863.

SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S.
BATH, September 14, 1864.

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.

VICE-PRESIDENTS.

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. Man-
chester
Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E.
Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.

The Rev. the Vice-Chancellor of the University of Cambridge
The 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.

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 Chevalier, B.D., F.R.A.S.
William Fairbairn, Esq., LL.D., F.R.S.

The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somer-
setshire
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.
W. Sanders, Esq., F.R.S., F.G.S.

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. Oslar, Esq., F.R.S.
J. T. Chance, Esq.
The Rev. Charles Evans, M.A.

LOCAL SECRETARIES.

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<p>WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 29, 1866.</p>	<p>His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire</p> <p>His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire</p> <p>The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire</p> <p>The Right Hon. J. E. Denison, M.P.</p> <p>J. C. Webb, Esq., High-Sheriff of Nottinghamshire</p> <p>Thomas Graham, Esq., F.R.S., Master of the Mint</p> <p>Joseph Hooker, Esq., M.D., F.R.S., F.I.S.</p> <p>John Russell Hind, Esq., F.R.S., F.R.A.S.</p> <p style="text-align: right;">T. Close, Esq.</p>	<p>Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. McCallan, M.A.</p>
<p>HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.</p>	<p>The Right Hon. the Earl of Airlie, K.T.</p> <p>The Right Hon. the Lord Kinnaird, K.T.</p> <p>Sir John Ogilvy, Bart., M.P.</p> <p>Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c.</p> <p>Sir David Baxter, Bart.</p> <p>Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh</p> <p>James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvador and St. Leonard, University of St. Andrews</p>	<p>J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.</p>
<p>JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.</p>	<p>The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk</p> <p>Sir John Peter Boileau, Bart., F.R.S.</p> <p>The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge</p> <p>Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S.</p> <p>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</p> <p>Thomas Brightwell, Esq.</p>	<p>Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.</p>
<p>PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.</p>	<p>The Right Hon. the Earl of Devon</p> <p>The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c.</p> <p>Sir John Bowring, LL.D., F.R.S.</p> <p>William B. Carpenter, Esq., M.D., F.R.S., F.L.S.</p> <p>Robert Wre Fox, Esq., F.R.S.</p> <p>W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.</p>	<p>Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.</p>
<p>PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.</p>	<p>The Right Hon. the Earl of Derby, LL.D., F.R.S.</p> <p>Sir Philip de Malpas Grey Egerton, Bart., M.P.</p> <p>The Right Hon. W. E. Gladstone, D.C.L., M.P.</p> <p>S. R. Graves, Esq., M.P.</p> <p>Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S.</p> <p>James P. Joule, Esq., LL.D., D.C.L., F.R.S.</p> <p>Joseph Mayer, Esq., F.S.A., F.R.G.S.</p>	<p>Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.</p>

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EDINBURGH, August 2, 1871.

W. E. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S.
BRIGHTON, August 14, 1872.

PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D.,
F.R.S., F.C.S.
BRADFORD, September 17, 1873.

PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S.
BELFAST, August 19, 1874.

SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S.
BRISTOL, August 25, 1875.

PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S.,
Hon. F.R.S.E.
GLASGOW, September 6, 1876.

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His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S.
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The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland
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Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S.
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Professor Christison, M.D., D.C.L., Pres. R.S.E.
Professor Balfour, F.R.S., F.R.S.E.

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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.
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The Right Hon. the Earl of Rosse, F.R.S.
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The Rev. Dr. Robinson, F.R.S.
Dr. Andrews, F.R.S.
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W. Sanders, Esq., F.R.S., F.G.S.

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Sir William Stirling Maxwell, Bart., M.A., M.P.
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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.
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Henry Willett, Esq.

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John H. Clarke, Esq.

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J. D. Marwick, Esq.

- PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E.**
 PLYMOUTH, August 15, 1877.
- 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.
- 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.
- 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.
- SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S.**
 YORK, August 31, 1881.
- O. 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 Earl of Mount-Edgcombe.**
 The Right Hon. Lord Blichford, K.C.M.G.
 William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S.
 William Fronde, Esq., M.A., C.E., F.R.S.
 Charles Spence Bate, Esq., F.R.S., F.L.S.
- 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.
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 The Right Hon. the Earl of Wharcliffe, F.R.G.S.
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 The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S.
 The Venerable Archdeacon Creyke, M.A.
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 F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department
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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. LORD RAYLEIGH, M.A., D.C.L.,
LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experi-
mental Physics in the University of Cambridge.
MONTREAL, August 27, 1884.

The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P.,
FR.D., LL.D., F.R.S., F.R.S.E., F.O.S.
ABERDEEN, September 9, 1885.

SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S.,
F.G.S., Principal and Vice-Chancellor of McGill Uni-
versity, Montreal, Canada
BIRMINGHAM, September 1, 1886.

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 The Right Rev. the Bishop of Salford
 The Right Worshipful the Mayor of Manchester
 The Right Worshipful the Mayor of Salford
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 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
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 The Worshipful the Mayor of Gateshead
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 Sir Andrew Fairbairn, M.A.

SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S.
 MANCHESTER, August 31, 1887.

SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E.
 BATH, September 5, 1888.

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.

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.

PRESIDENTS.

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.

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.

DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.O.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford.
 NOTTINGHAM, September 13, 1893.

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.

VICE-PRESIDENTS.

The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire
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 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. Illeweilyn, 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

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.
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 Professor Sir Douglas MacLagan, M.D., Pres. R.S.E.
 Professor Sir William Turner, F.R.S., F.R.S.E.
 Professor F. G. Tait, M.A., F.R.S.E.
 Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres. C.S.

His Grace the Duke of St. Albans, Lord-Lieut. of Nottinghamshire
 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 ..
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1906.

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 IPSWICH, September 11, 1895.

SIR JOSEPH LISTER, Bart., D.O.L., LL.D., President of the Royal Society.....
 LIVERPOOL, September 16, 1896.

SIR JOHN EVANS, K.O.B., D.C.L., LL.D., Sc.D., Treas. R.S., F.S.A., For. Sec. G.S......
 TORONTO, August 18, 1897.

SIR WILLIAM CROOKES, F.R.S., V.P.C.S......
 BRISTOL, September 7, 1898.

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DOVER, September 13, 1899.

PROFESSOR SIR WILLIAM TURNER, M.B., D.Sc.,
D.O.L., LL.D., F.R.S.
BRADFORD, September 5, 1900.

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The Major-General Commanding the South-Eastern District.
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Harold Brodrick, Esq., M.A.
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 BELFAST, September 10, 1902.

SIR NORMAN LOCKYER, K.O.B., LL.D., F.R.S., Corres-
 pondant de l'Institut de France
 SOUTHPORT, September 9, 1903.

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 Alexander Peckover, Esq., LL.D., Lord Lieutenant of Cambridgeshire.
 Arthur Hall, Esq., M.A., D.L., High Sheriff of Cambridgeshire and Huntingdonshire
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 The Very Rev. H. Montagu Butler, D.D., Master of Trinity
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 Joseph Martin, Esq., Chairman of the Isle of Ely County Council
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 F.R.S., Chancellor of the University of Edinburgh
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PROFESSOR E. RAY LANKESTER, M.A., LL.D., D.Sc., F.R.S., F.L.S., Director of the Natural History Departments of the British Museum, YORK, August 1, 1906.

His Grace the Archbishop of York, D.D., D.C.L., M.A.
 The Right Hon. the Lord Mayor of York
 The High Sheriff of Yorkshire
 The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S.
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 Tempest Anderson, M.D., D.Sc., President of the Yorkshire Philo-
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 John Stephenson Rowntree

Henry Craven.
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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. Jellet, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Ran- dall 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. Southamp- ton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmal, W. M. Hicks, A. John- son, 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.

Date and Place	Presidents	Secretaries
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. ...	A. P. Chattock, J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1899. Dover	Prof. J. H. Poynting, F.R.S.	J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1900. Bradford ...	Dr. J. Larmor, F.R.S.— <i>Dep. of Astronomy</i> , Dr. A. A. Common, F.R.S.	P. H. Cowell, A. Fowler, C. H. Lees, C. J. L. Wagstaffe, W. Watson, E. T. Whittaker.
1901. Glasgow ...	Major P. A. MacMahon, F.R.S.— <i>Dep. of Astronomy</i> , Prof. H. H. Turner, F.R.S.	H. S. Carslaw, C. H. Lees, W. Stewart, Prof. L. R. Wilberforce.
1902. Belfast.....	Prof. J. Purser, LL.D., M.R.I.A.— <i>Dep. of Astronomy</i> , Prof. A. Schuster, F.R.S.	H. S. Carslaw, A. R. Hinks, A. Larmor, C. H. Lees, Prof. W. B. Morton, A. W. Porter.
1903. Southport	C. Vernon Boys, F.R.S.— <i>Dep. of Astronomy and Meteorology</i> , Dr. W. N. Shaw, F.R.S.	D. E. Benson, A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, J. Loton, A. W. Porter.
1904. Cambridge	Prof. H. Lamb, F.R.S.— <i>Sub-Section of Astronomy and Cosmical Physics</i> , Sir J. Eliot, K.C.I.E., F.R.S.	A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, Dr. W. J. S. Lockyer, A. W. Porter, W. C. D. Whetham.
1905. South Africa	Prof. A. R. Forsyth, M.A., F.R.S.	A. R. Hinks, S. S. Hough, R. T. A. Innes, J. H. Jeans, Dr. C. H. Lees.
1906. York.....	Principal E. H. Griffiths, F.R.S.	Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter, H. Dennis Taylor.

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.

Date and Place	Presidents	Secretaries
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. Hera- path.
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. Southamp- ton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford.....	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.....	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E. ...	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast.....	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sul- livan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Rey- nolds.
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. Rus- sell, F. Sutton.

Date and Place	Presidents	Secretaries
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. Y. 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.
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.	P. P. Bedson, H. B. Dixon, H. F. 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.

Date and Place	Presidents	Secretaries
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.
1900. Bradford ...	Prof. W. H. Perkin, F.R.S. ...	W. M. Gardner, F. S. Kipping, W. J. Pope, T. K. Rose.
1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose.
1902. Belfast	Prof. E. Divers, F.R.S.....	R. F. Blake, M. O. Forster, Prof. G. G. Henderson, Prof. W. J. Pope.
1903. Southport	Prof. W. N. Hartley, D.Sc., F.R.S.	Dr. M. O. Forster, Prof. G. G. Hen- derson, J. Ohm, Prof. W. J. Pope.
1904. Cambridge	Prof. Sydney Young, F.R.S....	Dr. M. O. Forster, Prof. G. G. Hen- derson, Dr. H. O. Jones, Prof. W. J. Pope.
1905. SouthAfrica	George T. Beilby	W. A. Caldecott, Dr. M. O. Forster, Prof. G. G. Henderson, C. F. Juritz.
1906. York.....	Prof. Wyndham R. Dunstan, F.R.S.	Dr. E. F. Armstrong, Prof. A. W. Crossley, S. H. Davies, Prof. W. J. Pope.

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.— <i>Geog.</i> , R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.— <i>Geog.</i> , G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.— <i>Geo-</i> <i>graphy</i> , Capt. H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.— <i>Geography</i> , Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.— <i>Geography</i> , Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.— <i>Geog.</i> , G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strick- land, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.— <i>Geog.</i> , G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, H. Murray, H. E. Strickland, J. Scoular.
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. Southamp- ton.	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.....	J. B. Jukes, Prof. Oldham, A. C. Ramsay.
1850. Edinburgh ¹	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

¹ Geography was constituted a separate Section, see page lxvii.

Date and Place	Presidents	Secretaries
SECTION C (<i>continued</i>).—GEOLOGY.		
1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. E. 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, G. Sanders, R. H. Scott.
1858. Leeds	William Hopkins, M.A., 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, F.R.S...	Prof. Harkness, E. Hull, J. W. 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. Warrington 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., F.R.S.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S.....	E. Hull, W. Pengelly, H. Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, F.R.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. Southamp- ton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.

Date and Place	Presidents	Secretaries
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 Archibald Geikie, F.R.S.	J. W. Gregory, G. W. Lamplugh, Capt. McDakin, Prof. H. A. Miers.
1900. Bradford ...	Prof. W. J. Sollas, F.R.S. ...	H. L. Bowman, Rev. W. L. Carter, G. W. Lamplugh, H. W. Monckton.
1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton.
1902. Belfast	Lieut.-Gen. C. A. McMahon, F.R.S.	H. L. Bowman, H. W. Monckton, J. St. J. Phillips, H. J. Seymour.
1903. Southport	Prof. W. W. Watts, M.A., M.Sc.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. W. Monckton.
1904. Cambridge	Aubrey Strahan, F.R.S.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. Woods.
1905. SouthAfrica	Prof. H. A. Miers, M.A., D.Sc., F.R.S.	H. L. Bowman, J. Lomas, Dr. Molengraaff, Prof. A. Young, Prof. R. B. Young.
1906. York.....	G. W. Lamplugh, F.R.S.	H. L. Bowman, Rev. W. L. Carter, Rev. W. Johnson, J. Lomas.

BIOLOGICAL SCIENCES.

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

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

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

Date and Place	Presidents	Secretaries
SECTION D.—ZOOLOGY AND BOTANY.		
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. Southamp- ton.	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. lxxv.]

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

Date and Place	Presidents	Secretaries
1864. Bath	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham 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.— <i>Dep. of Physiol.</i> , Prof. Humphry, F.R.S.— <i>Dep. of Anthropol.</i> , 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.— <i>Dep. of Zool. and Bot.</i> , 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.— <i>Dep. of Physiology</i> , 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.— <i>Dep. of Bot. and Zool.</i> , C. Spence Bate, F.R.S.— <i>Dep. of Ethno.</i> , 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.— <i>Dep. of Anat. and Physiol.</i> , Prof. M. Foster, M.D., F.L.S.— <i>Dep. of Ethno.</i> , 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.— <i>Dep. of Bot. and Zool.</i> , Prof. Wyville Thomson, F.R.S.— <i>Dep. of Anthropol.</i> , 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.— <i>Dep. of Anat. and Physiol.</i> , Dr. Burdon Sanderson, F.R.S.— <i>Dep. of Anthropol.</i> , 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.— <i>Dep. of Anat. and Physiol.</i> , Prof. Rutherford, M.D.— <i>Dep. of Anthropol.</i> , Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.— <i>Dep. of Zool. and Bot.</i> , Dr. Hooker, C.B., Pres. R.S.— <i>Dep. of Anthropol.</i> , 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.— <i>Dep. of Anat. and Physiol.</i> , Prof. Cleland, F.R.S.— <i>Dep. of Anth.</i> , 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.— <i>Dep. of Zool. and Bot.</i> , Prof. A. Newton, F.R.S.— <i>Dep. of Anat. and Physiol.</i> , Dr. J. G. McKendrick.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.

¹ The title of Section D was changed to Biology.

Date and Place	Presidents	Secretaries
1877. Plymouth...	J. Gwyn Jeffreys, F.R.S.— <i>Dep. of Anat. and Physiol.</i> , Prof. Macalister.— <i>Dep. of Anthropol.</i> , 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.— <i>Dep. of Anthropol.</i> , Prof. Huxley, Sec. R.S.— <i>Dep. of Anat. and Physiol.</i> , 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.— <i>Dep. of Anthropol.</i> , E. B. Tylor, D.C.L., F.R.S.— <i>Dep. of Anat. and Physiol.</i> , Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, F.R.S.— <i>Dep. of Anat. & Physiol.</i> , F. M. Balfour, F.R.S.— <i>Dep. of Anthropol.</i> , F. W. Rudler.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.....	R. Owen, F.R.S.— <i>Dep. of Anthropol.</i> , Prof. W. H. Flower, F.R.S.— <i>Dep. of Anat. and Physiol.</i> , 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. Southamp- ton.	Prof. A. Gamgee, M.D., F.R.S.— <i>Dep. of Zool. and Bot.</i> , Prof. M. A. Lawson, F.L.S.— <i>Dep. of Anthropol.</i> , 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.— <i>Dep. of Anthropol.</i> , 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.
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.

¹ Anthropology was made a separate Section, see p. lxxiii.

Date and Place	Presidents	Secretaries
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.
1900. Bradford ...	Dr. R. H. Traquair, F.R.S. ...	W. Garstang, J. G. Kerr, T. H. Taylor, Swale Vincent.
1901. Glasgow ...	Prof. J. Cossar Ewart, F.R.S.	J. G. Kerr, J. Rankin, J. Y. Simpson.
1902. Belfast.....	Prof. G. B. Howes, F.R.S. ...	Prof. J. G. Kerr, R. Patterson, J. Y. Simpson.
1903. Southport	Prof. S. J. Hickson, F.R.S. ...	Dr. J. H. Ashworth, J. Barcroft, A. Quayle, Dr. J. Y. Simpson, Dr. H. W. M. Tims.
1904. Cambridge	William Bateson, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Prof. J. Y. Simpson, Dr. H. W. M. Tims.
1905. SouthAfrica	G. A. Boulenger, F.R.S.	Dr. Pakes, Dr. Purcell, Dr. H. W. M. Tims, Prof. J. Y. Simpson.
1906. York.....	J. J. Lister, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Oxley Grabham, Dr. H. W. M. Tims.

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.

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

Date and Place	Presidents	Secretaries
SECTION E.—PHYSIOLOGY.		
1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	J. Butter, J. Fuge, R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southamp- ton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sar- gent.
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.	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. Birming- ham 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. lix.]

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, E. 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.

¹ Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lxii). Section E, being then vacant was assigned in 1851 to Geography.

² Vide note on page lxi.

Date and Place	Presidents	Secretaries
1857. Dublin.....	Rev. Dr. J. Henthorn Todd, Pres.R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, 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 Crawford, 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.

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, Cle- ments 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, B.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 Thom- son, 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. Southamp- ton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin- Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.

Date and Place	Presidents	Secretaries
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.....	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sullivan, 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. Dalglish, 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.
1900. Bradford ...	Sir George S. Robertson, K.C.S.I.	H. N. Dickson, E. Heawood, E. R. Wethey.
1901. Glasgow ...	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson, E. Heawood, G. Sandeman, A. C. Turner.
1902. Belfast ...	Sir T. H. Holdich, K.C.B. ...	G. G. Chisholm, E. Heawood, Dr. A. J. Herbertson, Dr. J. A. Lindsay.
1903. Southport	Capt. E. W. Creak, R.N., C.B., F.R.S.	E. Heawood, Dr. A. J. Herbertson, E. A. Reeves, Capt. J. C. Underwood.
1904. Cambridge	Douglas W. Freshfield.....	E. Heawood, Dr. A. J. Herbertson, H. Y. Oldham, E. A. Reeves.
1905. SouthAfrica	Adm. Sir W. J. L. Wharton, R.N., K.C.B., F.R.S.	A. H. Cornish-Bowden, F. Flowers, Dr. A. J. Herbertson, H. Y. Oldham.
1906. York.....	Rt. Hon. Sir George Goldie, K.C.M.G., F.R.S.	E. Heawood, Dr. A. J. Herbertson, E. A. Reeves, G. Yeld.

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.

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

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

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.

Date and Place	Presidents	Secretaries
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. McNeel 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. ...	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. Southamp- ton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S. ...	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, 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.

Date and Place	Presidents	Secretaries
1899. Dover	H. Higgs, LL.B.	A. L. Bowley, E. Cannan, Prof. A. W. Flux, Rev. G. Sarson.
1900. Bradford ...	Major P. G. Craigie, V.P.S.S.	A. L. Bowley, E. Cannan, S. J. Chapman, F. Hooper.
1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan, S. J. Chapman.
1902. Belfast ...	E. Cannan, M.A., LL.D.	A. L. Bowley, Prof. S. J. Chapman, Dr. A. Duffin
1903. Southport	E. W. Brabrook, C.B.	A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg, G. Lloyd.
1904. Cambridge	Prof. Wm. Smart, LL.D.	J. E. Bidwell, A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg.
1905. SouthAfrica	Rev. W. Cunningham, D.D., D.Sc.	R. à Ababrelton, A. L. Bowley, Prof. H. E. S. Fremantle, H. O. Meredith.
1906. York.....	A. L. Bowley, M.A.	Prof. S. J. Chapman, D. H. Macgregor, H. O. Meredith, B. S. Rowntree.

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. Southamp- ton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson ..	Dr. Lees, David Stephenson.
1851. Ipswich ...	William Cubitt, F.R.S.	John Head, Charles Manby.
1852. Belfast.....	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, 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.

Date and Place	Presidents	Secretaries
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. Brownne, 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. Southamp- ton.	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.
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, Hou. 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. Poplewell, 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.

Date and Place	Presidents	Secretaries
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.
1900. Bradford ¹	Sir Alex. R. Binnie, M.Inst.C.E.	Prof. T. H. Beare, C. F. Charnock, Prof. S. Dunkerley, W. A. Price.

SECTION G.—ENGINEERING.

1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W. E. Dalby, W. A. Price.
1902. Belfast ...	Prof. J. Perry, F.R.S.	M. Barr, W. A. Price, J. Wylie.
1903. Southport	C. Hawksley, M.Inst.C.E. ...	Prof. W. E. Dalby, W. T. Maccall, W. A. Price.
1904. Cambridge	Hon. C. A. Parsons, F.R.S. ...	J. B. Peace, W. T. Maccall, W. A. Price.
1905. SouthAfrica	Col. Sir C. Scott-Moncrieff, G.C.S.I., K.C.M.G., R.E.	W. T. Maccall, W. B. Marshall, Prof. H. Payne, E. Williams.
1906. York.....	J. A. Ewing, F.R.S.	W. T. Maccall, W. A. Price, J. Trifitt.

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.

¹ The title of Section G was changed to Engineering.

Date and Place	Presidents	Secretaries
1900. Bradford ...	Prof. John Rhys, M.A.....	Rev. E. Armitage, H. Balfour, W. Crooke, J. L. Myres.
1901. Glasgow ...	Prof. D. J. Cunningham, F.R.S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres.
1902. Belfast ...	Dr. A. C. Haddon, F.R.S. ...	R. Campbell, Prof. A. F. Dixon, J. L. Myres.
1903. Southport	Prof. J. Symington, F.R.S. ...	E. N. Fallaize, H. S. Kingsford, E. M. Littler, J. L. Myres.
1904. Cambridge	H. Balfour, M.A.	W. L. H. Duckworth, E. N. Fallaize, H. S. Kingsford, J. L. Myres.
1905. SouthAfrica	Dr. A. C. Haddon, F.R.S. ...	A. R. Brown, A. von Dessauer, E. S. Hartland.
1906. York.....	E. Sidney Hartland, F.S.A....	Dr. G. A. Auden, E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrub-sall.

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

1894. Oxford.....	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof. F. Gotch, Dr. J. S. Haldane, M. S. Pembrey.
1896. Liverpool ..	Dr. W. H. Gaskell, F.R.S. ...	Prof. R. Boyce, Prof. C. S. Sherrington.
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.
1901. Glasgow ...	Prof. J. G. McKendrick, F.R.S.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson.
1902. Belfast ...	Prof. W. D. Halliburton, F.R.S.	J. Barcroft, Dr. W. A. Osborne, Dr. C. Shaw.
1904. Cambridge	Prof. C. S. Sherrington, F.R.S.	J. Barcroft, Prof. T. G. Brodie, Dr. L. E. Shore.
1905. SouthAfrica	Col. D. Bruce, C.B., F.R.S. ...	J. Barcroft, Dr. Baumann, Dr. Mackenzie, Dr. G. W. Robertson, Dr. Stanwell.
1906. York.....	Prof. F. Gotch, F.R.S.	J. Barcroft, Dr. J. M. Hamill, Prof. J. S. Macdonald, Dr. D. S. Long.

SECTION K.—BOTANY.

1895. Ipswich ...	W. T. Thiselton-Dyer, F.R.S.	A. C. Seward, Prof. F. E. Weiss.
1896. Liverpool...	Dr. D. H. Scott, F.R.S.	Prof. Harvey Gibson, A. C. Seward, Prof. F. E. Weiss.
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.
1900. Bradford ...	Prof. S. H. Vines, F.R.S.	A. C. Seward, H. Wager, W. West.
1901. Glasgow ...	Prof. I. B. Balfour, F.R.S. ...	D. T. Gwynne-Vaughan, G. F. Scott-Elliot, A. C. Seward, H. Wager.
1902. Belfast ...	Prof. J. R. Green, F.R.S.	A. G. Tansley, Rev. C. H. Waddell, H. Wager, R. H. Yapp.
1903. Southport	A. C. Seward, F.R.S.	H. Ball, A. G. Tansley, H. Wager, R. H. Yapp.
1904. Cambridge	Francis Darwin, F.R.S.	Dr. F. F. Blackman, A. G. Tansley, H. Wager, T. B. Wood, R. H. Yapp.
1905. SouthAfrica	Harold Wager, F.R.S.	R. P. Gregory, Dr. Marloth, Prof. Pearson, Prof. R. H. Yapp.
1906. York.....	Prof. F. W. Oliver, F.R.S. ...	Dr. A. Burt, R. P. Gregory, Prof. A. G. Tansley, Prof. R. H. Yapp.

SECTION L.—EDUCATIONAL SCIENCE.

Date and Place	Presidents	Secretaries
1901. Glasgow ...	Sir John E. Gorst, F.R.S. ...	R. A. Gregory, W. M. Heller, R. Y. Howie, C. W. Kimmins, Prof. H. L. Withers.
1902. Belfast ...	Prof. H. E. Armstrong, F.R.S.	Prof. R. A. Gregory, W. M. Heller, R. M. Jones, Dr. C. W. Kimmins, Prof. H. L. Withers.
1903. Southport	Sir W. de W. Abney, K.C.B., F.R.S.	Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins, Dr. H. L. Snape.
1904. Cambridge	Bishop of Hereford, D.D. ...	J. H. Flather, Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins.
1905. SouthAfrica	Prof. Sir R. C. Jebb, D.C.L., M.P.	A. D. Hall, Prof. Hele-Shaw, Dr. C. W. Kimmins, J. R. Whitton.
1906. York.....	Prof. M. E. Sadler, LL.D. ...	Prof. R. A. Gregory, W. M. Heller, Hugh Richardson.

CHAIRMEN AND SECRETARIES OF THE CONFERENCES OF DELEGATES OF CORRESPONDING SOCIETIES.

Date and Place	Chairmen	Secretaries
1885. Aberdeen ...	Francis Galton, F.R.S.....	Prof. Meldola.
1886. Birmingham	Prof. A. W. Williamson, F.R.S.	Prof. Meldola, F.R.S.
1887. Manchester	Prof. W. Boyd Dawkins, F.R.S.	Prof. Meldola, F.R.S.
1888. Bath	John Evans, F.R.S.	Prof. Meldola, F.R.S.
1889. Newcastle-upon-Tyne	Francis Galton, F.R.S.....	Prof. G. A. Lebour.
1890. Leeds	G. J. Symons, F.R.S.	Prof. Meldola, F.R.S.
1891. Cardiff	G. J. Symons, F.R.S.	Prof. Meldola, F.R.S.
1892. Edinburgh	Prof. Meldola, F.R.S.	T. V. Holmes.
1893. Nottingham	Dr. J. G. Garson	T. V. Holmes.
1894. Oxford	Prof. Meldola, F.R.S.	T. V. Holmes.
1895. Ipswich ...	G. J. Symons, F.R.S.	T. V. Holmes.
1896. Liverpool...	Dr. J. G. Garson	T. V. Holmes.
1897. Toronto ...	Prof. Meldola, F.R.S.	J. Hopkinson.
1898. Bristol	W. Whitaker, F.R.S.	T. V. Holmes.
1899. Dover	Rev. T. R. R. Stebbing, F.R.S.	T. V. Holmes.
1900. Bradford ...	Prof. E. B. Poulton, F.R.S. ...	T. V. Holmes.
1901. Glasgow ...	F. W. Rudler, F.G.S.	Dr. J. G. Garson, A. Somerville.
1902. Belfast.....	Prof. W. W. Watts, F.G.S. ...	E. J. Bles.
1903. Southport	W. Whitaker, F.R.S.	F. W. Rudler.
1904. Cambridge	Prof. E. H. Griffiths, F.R.S.	F. W. Rudler.
1905. London ...	Dr. A. Smith Woodward, F.R.S.	F. W. Rudler.
1906. York.....	Sir Edward Brabrook, C.B....	F. W. Rudler.

LIST OF EVENING DISCOURSES.

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.

Date and Place	Lecturer	Subject of Discourse
1843. Cork	Prof. Owen, M.D., F.R.S..... Prof. E. Forbes, F.R.S.....	The Dinornis of New Zealand. The Distribution of Animal Life in the Ægean Sea.
1844. York	Dr. Robinson	The Earl of Rosse's Telescope.
	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. Southamp- ton.	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.
1848. Swansea ...	Hugh E. Strickland, F.G.S....	The Dodo (<i>Didus ineptus</i>).
	John Percy, M.D., F.R.S.....	Metallurgical Operations of Swansea and its Neighbourhood.
1849. Birmingham	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
1851. Ipswich ...	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their Changes of Form.
	G. B. Airy, F.R.S., Astronomer 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.
1854. Liverpool...	Robert Hunt, F.R.S.....	The present state of Photography.
	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.
1857. Dublin	W. R. Grove, F.R.S.	Correlation of Physical Forces.
	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.

Date and Place	Lecturer	Subject of Discourse
1860. Oxford.....	Rev. Prof. Walker, F.R.S. ... Captain Sherard Osborn, R.N.	Physical Constitution of the Sun. Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S. G. B. Airy, F.R.S., Astron. Royal	Spectrum Analysis. The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S. Prof. Odling, F.R.S.....	The Forms and Action of Water. Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S..... James Glaisher, F.R.S.....	The Chemistry of the Galvanic Battery considered in relation to Dynamics. The Balloon Ascents made for the British Association.
1864. Bath.....	Prof. Roscoe, F.R.S.	The Chemical Action of Light.
1865. Birmingham	Dr. Livingstone, F.R.S. J. Beete Jukes, F.R.S.....	Recent Travels in Africa. 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.
1867. Dundee.....	Dr. J. D. Hooker, F.R.S..... Archibald Geikie, F.R.S..... Alexander Herschel, F.R.A.S.	Insular Floras. The Geological Origin of the present Scenery of Scotland. The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S.....	Archæology of the early Buddhist Monuments.
1869. Exeter	Dr. W. Odling, F.R.S. Prof. J. Phillips, LL.D., F.R.S. J. Norman Lockyer, F.R.S. ..	Reverse Chemical Actions. Vesuvius. The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S. Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	The Scientific Use of the Imagination. 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.
1872. Brighton ...	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1873. Bradford ...	Prof. P. Martin Duncan, M.B., F.R.S. Prof. W. K. Clifford ...	Insect Metamorphosis. The Aims and Instruments of Scientific Thought.
1874. Belfast	Prof. W. C. Williamson, F.R.S. Prof. Clerk Maxwell, F.R.S. Sir John Lubbock, Bart., M.P., F.R.S. Prof. Huxley, F.R.S.	Coal and Coal Plants. Molecules. Common Wild Flowers considered in relation to Insects. The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S. F. J. Bramwell, F.R.S.....	The Colours of Polarised Light. Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E. Sir Wyville Thomson, F.R.S.	Force. The 'Challenger' Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S. Prof. Odling, F.R.S.....	Physical Phenomena connected with the Mines of Cornwall and Devon. The New Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S. Prof. Dewar, F.R.S.....	Animal Intelligence. Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S. Prof. E. Ray Lankester, F.R.S.	Radiant Matter. Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S. Francis Galton, F.R.S.....	Primeval Man. Mental Imagery.

Date and Place	Lecturer	Subject of Discourse
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. Southamp- ton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
1883. Southport	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
1884. Montreal ...	Prof. J. G. McKendrick.	Galvanic and Animal Electricity.
	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Re- searches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
1886. Birmingham	John Murray, F.R.S.E.....	The Great Ocean Basins.
	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
1887. Manchester	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
1888. Bath.....	Col. Sir F. de Winton	Explorations in Central Africa.
	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
1889. Newcastle- upon-Tyne	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
	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.
1891. Cardiff	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
1892. Edinburgh	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
	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 So- cialism.
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. W. C. 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.
1900. Bradford ...	Prof. F. Gotch, F.R.S.	Animal Electricity.
	Prof. W. Stroud.	Range Finders.
1901. Glasgow ...	Prof. W. Ramsay, F.R.S.	The Inert Constituents of the Atmosphere.
	F. Darwin, F.R.S.	The Movements of Plants.
1902. Belfast ...	Prof. J. J. Thomson, F.R.S....	Becquerel Rays and Radio-activity.
	Prof. W. F. R. Weldon, F.R.S.	Inheritance.

Date and Place	Lecturer	Subject of Discourse
1903. Southport	Dr. R. Munro	Man as Artist and Sportsman in the Palæolithic Period.
	Dr. A. Rowe	The Old Chalk Sea, and some of its Teachings.
1904. Cambridge	Prof. G. H. Darwin, F.R.S....	Ripple-Marks and Sand-Dunes.
	Prof. H. F. Osborn	Palæontological Discoveries in the Rocky Mountains.
1905. South Africa: Cape Town ...	Prof. E. B. Poulton, F.R.S. ...	W. J. Burchell's Discoveries in South Africa.
Durban ...	C. Vernon Boys, F.R.S.	Some Surface Actions of Fluids.
	Douglas W. Freshfield.....	The Mountains of the Old World.
Pietermaritzburg	Prof. W. A. Herdman, F.R.S.	Marine Biology.
	Col. D. Bruce, C.B., F.R.S....	Sleeping Sickness.
Johannesburg	H. T. Ferrar	The Cruise of the 'Discovery.'
	Prof. W. E. Ayrton, F.R.S. ...	The Distribution of Power.
Pretoria ...	Prof. J. O. Arnold.....	Steel as an Igneous Rock.
	A. E. Shipley, F.R.S.	Fly-borne Diseases: Malaria, Sleeping Sickness, &c.
Bloemfontein...	A. R. Hinks	The Milky Way and the Clouds of Magellan.
Kimberley ...	Sir Wm. Crookes, F.R.S.	Diamonds.
	Prof. J. B. Porter	The Bearing of Engineering on Mining.
Bulawayo ...	D. Randall-MacIver	The Ruins of Rhodesia.
1906. York.....	Dr. Tempest Anderson.....	Volcanoes.
	Dr. A. D. Waller, F.R.S.	The Electrical Signs of Life, and their Abolition by Chloroform.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Lecture
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.

Date and Place	Lecturer	Subject of Lecture
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.
1900. Bradford ...	Prof. S. P. Thompson, F.R.S.	Electricity in the Industries.
1901. Glasgow ...	H. J. Mackinder, M.A.....	The Movements of Men by Land and Sea.
1902. Belfast.....	Prof. L. C. Miall, F.R.S.	Gnats and Mosquitoes.
1903. Southport	Dr. J. S. Flett	Martinique and St. Vincent: the Eruptions of 1902.
1904. Cambridge	Dr. J. E. Marr, F.R.S.	The Forms of Mountains.
1906. York.....	Prof. S. P. Thompson, F.R.S.	The Manufacture of Light.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE YORK MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Principal E. H. Griffiths, F.R.S. *Vice-Presidents.*—Prof. H. L. Callendar, F.R.S. ; Prof. A. R. Forsyth, F.R.S. ; Prof. A. Gray, F.R.S. *Secretaries.*—Prof. A. W. Porter, B.Sc. (*Recorder*), L. N. G. Filon, D.Sc. ; Dr. J. A. Harker ; A. R. Hinks, M.A. ; H. Dennis Taylor.

SECTION B.—CHEMISTRY.

President.—Prof. Wyndham R. Dunstan, F.R.S. *Vice-Presidents.*—G. T. Beilby, F.R.S. ; A. Vernon Harcourt, F.R.S. ; Sir William H. Perkin, F.R.S. ; Prof. A. Smithells, F.R.S. ; Prof. W. A. Tilden, F.R.S. *Secretaries.*—Prof. W. J. Pope, F.R.S. (*Recorder*) ; Dr. E. F. Armstrong ; Prof. A. W. Crossley, D.Sc. ; S. H. Davies.

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President.—J. J. Lister, F.R.S. *Vice-Presidents.*—G. A. Boulenger, F.R.S. ; Prof. G. C. Bourne ; Prof. Jungersen ; Prof. Pelseneer ; A. E. Shipley, F.R.S. *Secretaries.*—H. W. Marett Tims, M.D. (*Recorder*) ; J. H. Ashworth, D.Sc. ; L. Doncaster, M.A. ; Oxley Grabham, M.A.

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President.—Right Hon. Sir George Taubman Goldie, K.C.M.G., D.C.L., F.R.S. *Vice-Presidents.*—Major C. F. Close, R.E., C.M.G. ;

Colonel D. A. Johnston, R.E., C.B. ; J. Scott Keltie, LL.D. ; H. R. Mill, LL.D. *Secretaries*.—E. Heawood (*Recorder*) ; A. J. Herbertson ; E. A. Reeves ; G. Yeld.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—A. L. Bowley, M.A. *Vice-Presidents*.—Major P. G. Craigie, C.B. ; Rev. W. Cunningham, D.D., D.Sc. *Secretaries*.—Prof. S. J. Chapman, M.A. (*Recorder*) ; D. H. Macgregor, M.A. ; H. O. Meredith, M.A. ; B. Seebohm Rowntree.

SECTION G.—ENGINEERING.

President.—J. A. Ewing, M.A., LL.D., F.R.S. *Vice-Presidents*.—J. A. F. Aspinall ; W. J. Cudworth ; Sir Andrew Noble, Bart., K.C.B. F.R.S. ; Sir W. H. Preece, K.C.B., F.R.S. ; Sir W. H. White, K.C.B., F.R.S. *Secretaries*.—W. A. Price, M.A. (*Recorder*) ; W. T. Maccall ; John Triffitt.

SECTION H.—ANTHROPOLOGY.

President.—E. Sidney Hartland, F.S.A. *Vice-Presidents*.—Dr. A. C. Haddon, F.R.S. ; D. G. Hogarth, M.A. *Secretaries*.—E. N. Fallaize, B.A. (*Recorder*) ; H. S. Kingsford, M.A. ; F. C. Shruballs, M.D. ; G. A. Auden, M.D.

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President.—Prof. Francis Gotch, M.A., D.Sc., F.R.S. *Vice-Presidents*.—Dr. Bevan-Lewis ; Sir T. Lauder Brunton, V.P.R.S. ; Sir A. E. Wright, F.R.S. *Secretaries*.—J. Barcroft, M.A. (*Recorder*) ; Prof. J. S. Macdonald, B.A. ; D. Sanderson Long, M.D. ; J. M. Hamill, M.D.

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President.—Prof. F. W. Oliver, D.Sc., F.R.S. *Vice-Presidents*.—D. H. Scott, F.R.S. ; Harold Wager, F.R.S. *Secretaries*.—Prof. A. G. Tansley, M.A. (*Recorder*) ; R. P. Gregory, M.A. ; Prof. R. H. Yapp, M.A. ; A. Burt, D.Sc.

SECTION L.—EDUCATIONAL SCIENCE.

President.—Prof. M. E. Sadler, LL.D. *Vice-Presidents*.—Sir Henry Craik, K.C.B., LL.D. ; Sir Philip Magnus, B.Sc., M.P. ; Col. Legard ; Dr. N. Bodington ; Sir T. Lauder Brunton, V.P.R.S. *Secretaries*.—W. M. Heller, B.Sc. (*Recorder*) ; Prof. R. A. Gregory ; Hugh Richardson, M.A.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

Chairman.—Sir Edward Brabrook, C.B., F.S.A. *Vice-Chairman*.—John Hopkinson, F.L.S. *Secretary*.—F. W. Rudler, I.S.O.

COMMITTEE OF RECOMMENDATIONS.

The President and Vice-Presidents of the Meeting ; the Presidents of former years ; the Trustees ; the General Treasurer ; the General Secretaries ; Principal Griffiths ; Prof. Porter ; Prof. Dunstan ; Prof. Pope ; G. W. Lamplugh ; H. L. Bowman ; J. J. Lister ; Dr. Marett Tims ; Sir George Goldie ; E. Heawood ; A. L. Bowley ; Prof. Chapman ; Dr. Ewing ; W. A. Price ; E. Sidney Hartland ; E. N. Fallaize ; Prof. Gotch ; J. Barcroft ; Prof. Oliver ; Prof. Tansley ; Prof. Sadler ; W. M. Heller ; Sir Edward Brabrook ; F. W. Rudler.

Dr.

THE GENERAL TREASURER'S ACCOUNT,

1905-1906.

RECEIPTS.

	£	s.	d.
Balance brought forward	1787	8	1
Life Compositions (including Transfers)	398	0	0
New Annual Members' Subscriptions	582	0	0
Annual Subscriptions	466	0	0
Sale of Associates' Tickets	425	0	0
Sale of Ladies' Tickets	181	0	0
Contribution from South African Association	500	0	0
Sale of Publications	160	16	3
Dividend on Consols	154	8	4
Dividend on India 3 per Cents.	102	12	0
Interest on Deposit.....	54	4	2
Balance of Grants returned :—			
Age of Stone Circles.....	£0	13	9
State of Solution of Proteids.....	1	9	8
		2	3
Donation	50	0	0
		5	

£4863 12 3

Investments.

	£	s.	d.
2½ per Cent. Consolidated Stock	£6507	10	5
India 3 per Cent. Stock	3600	0	0
	£10,101	10	5
Sir Frederick Bramwell's Gift, 2½ per Cent. Self-cumulating Consolidated Stock	61	13	8
	£10,163	4	1

JOHN PERRY, *General Treasurer.*

from July 1, 1905, to June 30, 1906.

Cr.

1905-1906.

PAYMENTS.

	£	s.	d.
Rent and Office Expenses (including Payments to Office of Works for repairs at Office)	161	9	5
Salaries, &c.	756	16	6
Printing, Binding, &c.....	1122	10	9
Payment of Grants made in South Africa:			
Electrical Standards	25	0	0
Seismological Observations.....	40	0	0
Magnetic Observations at Falmouth	50	0	0
Magnetic Survey of South Africa	99	12	6
Wave-length Tables of Spectra.....	5	0	0
Study of Hydro-Aromatic Substances	25	0	0
Aromatic Nitramines	10	0	0
Fauna and Flora of the British Trias	7	8	11
Crystalline Rocks of Anglesey	30	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Frog	10	0	0
Higher Crustacea	15	0	0
Freshwater Fishes of South Africa	50	0	0
Rainfall and Lake and River Discharge.....	10	0	0
Excavations in Crete.....	100	0	0
Lake Village at Glastonbury	40	0	0
Excavations on Roman Sites in Britain	30	0	0
Anthropometric Investigations in the British Isles.....	30	0	0
State of Solution of Proteids.....	20	0	0
Metabolism of Individual Tissues	20	0	0
Effect of Climate upon Health and Disease	20	0	0
Research on South African Cycads	14	19	4
Peat Moss Deposits	25	0	0
Studies suitable for Elementary Schools.....	5	0	0
Corresponding Societies Committee.....	25	0	0
	882	0	9
	2922	17	5
On deposit at Bradford District Bank	1172	6	1
Balance at Bank of England (Western Branch)	£936	9	11
Less Cheques not presented.....	169	12	6
	766	17	5
Cash in hand.....		1	11 4
	£4863	12	3

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 Balance at the Bankers', and have ascertained that the Investments are registered in the names of the Trustees.

Approved—

HERBERT MCLEOD, }
EDWARD BRABROOK, } *Auditors.*

W. B. KEEN, *Chartered Accountant,*
3 Church Court, Old Jewry, E.C.
July 26, 1906.

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., F.R.S.	—	—
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., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. F.R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D. F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	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., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	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., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, O.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	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., F.R.S.	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., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	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	23
1882, Aug. 23	Southampton	Dr. O. 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.O.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.O.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
1900, Sept. 5	Bradford	Sir William Turner, D.O.L., F.R.S.	267	13
1901, Sept. 11	Glasgow	Prof. A. W. Rucker, D.Sc., Sec. R.S.	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15	South Africa	Prof. G. H. Darwin, LL.D., F.R.S.	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10

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

at Annual Meetings of the Association.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	23	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
123	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	764	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	1296 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	1194 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
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900
374	131	794	246	20	1912	2046 0 0	945 0 0	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937 †	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906

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

† Including 848 Members of the South African Association.

OFFICERS AND COUNCIL, 1906-1907.

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HIS MAJESTY THE KING.

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

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Dr. J. G. Garson.

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Sir Edward Brabrook, C.B. | Professor H. McLeod, F.R.S.

Annual Report of the Council, 1905-06.

I. For the third time in its history, the British Association in 1905 held its Annual Meeting beyond the United Kingdom. The Council desire to express their high appreciation of the cordial reception, hospitalities, and privileges extended to the Officers and Members of the Association throughout South Africa by the representatives of the several Colonies and Administrations, and in particular to recognise the admirable and arduous work performed by the Local Committees under the general direction of Sir David Gill, as Chairman of the Central Organising Committee. A detailed account of the Meeting has been published in the Annual Report, together with information in regard to the foundation of a Medal and Scholarship for South African Students in commemoration of the event.

On the proposal of the General Treasurer, the Council resolved to add to the South Africa Medal Fund the balance of the special fund raised to meet extraordinary expenditure in connection with the Meeting.

The Council have to deplore the deaths of Sir Richard Jebb and Admiral Sir W. Wharton, who held office as Presidents of Section and accompanied the Association during the tour in South Africa.

II. Sir David Gill, K.C.B., F.R.S., has been nominated to fill the office of President for 1907.

The Dublin Reception Committee have decided to renew their invitation for 1908; and a deputation will present it to the General Committee at the Meeting in York.

III. The following Resolutions, adopted by the General Committee, have been considered by the Council, and action has been taken in accordance with the recommendations made therein:—

From Section A.

(i) The Committee, being of opinion that the completion of the Geodetic Arc from the South to the North of Africa is of the utmost scientific importance, and that the establishment of a Topographical Survey is of an importance that is at once scientific and economic, respectfully request the Council to make representations in such form as they think fit to urge upon the British South Africa Company the desirability of taking advantage of the present favourable opportunity for joining up the triangulation north and south of the Zambesi, and also to urge upon the Governments of the South African Colonies the immense practical and economic importance of commencing the topographical survey.

(ii) The Committee desire to draw attention to the importance of a Magnetic Survey of South Africa, and respectfully request the Council of

the Association to approach the Cape Government with a view to urging on them the great advantages which would accrue to Science and to South Africa if the Government would further support and assist the Survey which has already been partly made by Professor Beattie and Professor Morrison, and for the continuation of which a Special Committee of the Association is being appointed to co-operate with these gentlemen.

§. A grant of 300*l.* from the Special South Africa Fund has been made by the Council to Sir David Gill, for the purpose of completing the connection between the Rhodesian and Transvaal triangulations along the thirtieth meridian of East longitude.

From Section H.

(i) That it is desirable that the Governments of the South African Colonies be urged to take all necessary steps to collect, record, and preserve the knowledge and observations of men, such as missionaries, administrators, and others, who were living in intimate relations with the native tribes before the advance of civilisation began to obscure and even obliterate all true traditions, customs, and habits of the South African peoples ; such steps to be taken without delay, especially in view of the old age and growing infirmities of most of the men referred to, and of the danger that with their deaths the knowledge which, if carefully recorded and preserved, would form a most valuable contribution towards the history of the aboriginal population, would be irrecoverably lost; and that the Council be recommended to communicate with the South African Association and suggest the appointment of a Committee to deal with the matter.

(ii) That, owing to the use by different writers and Government authorities of various names for the same groups of South African natives, much confusion and difficulty have arisen in anthropological and historical literature ; that it is consequently desirable that Government authorities and others should confer as to the proper nomenclature of such groups (clans, tribes, and nations), with a view to ascertaining their inter-relationships, and to suggesting the most appropriate name for each group, and the best method of spelling that name phonetically ; and that the Council be recommended to communicate with the South African Association and take such other steps as may conduce to this object.

(iii) That the Committee are of opinion that it would conduce to the greater efficiency of officers who have to administer native affairs, and contribute to the advancement of anthropological science, as well as prove of considerable advantage to the well-being of the natives themselves, if opportunity could be given to such officers before or after their appointment to study comparative ethnology for at least two terms in one of the Universities of the United Kingdom which presents facilities for the study ; and that in the case of junior officers already on active service such a course of study would facilitate their comprehension of native institutions and ideas, and help to render their services more efficient ; and the Committee recommends the Council to take steps for the purpose of bringing this matter before the proper authorities.

IV. In view of the tentative proposals for Annual Meetings of the Association to be held at Colombo and Winnipeg, the Council discussed

the propriety of holding another Meeting beyond the United Kingdom in or before the year 1910, and decided to postpone to a future date the formal consideration of this matter.

V. The President, Sir George Darwin, represented the Association and presented an Address of Congratulation to the American Philosophical Society on the occasion of the celebration at Philadelphia of the two hundredth anniversary of the birth of Benjamin Franklin. Professor Meldola represented the Association at the Sixth International Congress of Applied Chemistry held at Rome; and Professor Herbert Cox was appointed a delegate to the International Mining Conference held in London.

VI. The following nominations are made by the Council :—

(i) Additional Vice-Presidents for the Meeting at York: Right Hon. Lord Avebury; Sir Hugh Bell; Mr. John Stephenson Rowntree.

(ii) Sir Edward W. Brabrook, Chairman; Mr. John Hopkinson, Vice-Chairman; and Mr. F. W. Rudler, Secretary, of the Conference of Delegates of Corresponding Societies to be held in York.

(iii) Members of the Corresponding Societies Committee for the ensuing year: Mr. W. Whitaker, Chairman; Mr. F. W. Rudler, Secretary; Rev. J. O. Bevan, Dr. Horace T. Brown, Dr. Vaughan Cornish, Dr. J. G. Garson, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Professor R. Meldola, Dr. H. R. Mill, Mr. C. H. Read, Rev. T. R. P. Stebbing, Professor W. W. Watts, and the General Officers of the Association.

(iv) Local Secretary for the Meeting at York: Mr. Henry Craven, the Town Clerk, in place of Mr. R. P. Dale, deceased.

VII. A Report has been received from the Corresponding Societies Committee, together with the list of the Corresponding Societies, and the titles of the more important papers, especially of those referring to local scientific investigations, published by the Societies during the year ending May 31, 1906.

VIII. A Committee, consisting of Professor Ray Lankester, Professor E. B. Poulton, Professor W. A. Herdman, and Professor Francis Gotch, appointed to inquire into the Position of Biology at the Royal College of Science, have submitted a Report which is now under the consideration of the Board of Education.

IX. Professor W. A. Herdman, F.R.S., has been nominated a Governor, to serve on the Council of the Marine Biological Association of the United Kingdom, in place of the late Professor Weldon.

X. The Council have received reports from the General Treasurer during the past year. His accounts from July 1, 1905, to June 30, 1906, have been audited, and are presented to the General Committee.

XI. In accordance with the regulations, the retiring members of the Council are as follows: Professor F. O. Bower; Professor H. L. Callendar; Professor A. Macalister; Sir A. Noble, Bart.; and Mr. Henry Higgs.

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 :—

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| <p>*Abney, Sir W., K.C.B., F.R.S.
 Bourne, G. C., D.Sc.
 Boys, C. Vernon, F.R.S.
 Brabrook, Sir Edward W., C.B.
 Brown, Dr. Horace T., F.R.S.
 Cunningham, Professor D. J., F.R.S.
 Dunstan, Professor W., F.R.S.
 Dyson, Professor F. W., F.R.S.
 Glazebrook, Dr. R. T., F.R.S.
 *Goldie, Sir G. Taubman, K.C.B., F.R.S.
 Gotch, Professor F., F.R.S.
 Haddon, Dr. A. C., F.R.S.</p> | <p>Hawksley, C., M.Inst.C.E.
 Langley, Professor J. N., F.R.S.
 McKendrick, Professor J. G., F.R.S.
 *Mitchell, Dr. P. Chalmers, F.R.S.
 Perkin, Professor W. H., F.R.S.
 Poulton, Professor E. B., F.R.S.
 Seward, A. C., F.R.S.
 Shaw, Dr. W. N., F.R.S.
 Shipley, A. E., F.R.S.
 Watts, Professor W. W., F.R.S.
 Woodward, Dr. A. Smith, F.R.S.</p> |
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XII. The following claims for admission to the General Committee have been allowed by the Council :—

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| <p>The Earl of Berkeley.
 Douglas Berridge.
 W. H. Lang.
 J. H. Leonard.
 R. C. Millar.</p> | <p>Professor M. C. Potter.
 Dr. A. E. Salter.
 S. A. Saunder.
 William West.
 Professor Worthington.</p> |
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XIII. A Committee, consisting of the President, the General Officers, the Assistant Secretary, Mr. Vernon Harcourt, Mr. John L. Myres, and Sir Edward Brabrook, appointed to draw up and present a report on the following proposals, have made a report which is herewith submitted to the General Committee :—

(I) THE COMMITTEE appointed by the Council on 1st June, under the terms of reference given in the Minutes of the Council held on that date, *recommend*—(i) That the Rules and Regulations be revised and co-ordinated, power being given to the Committee to include in the body of the Rules such Standing Orders and Resolutions as by precedent and practice have become virtual Rules and Regulations of the Association ; (ii) That the standing matter hitherto published continuously and in consecutive order in the introductory pages of the Annual Report be in future published in quinquennial periods, as from the beginning of the Century, or Second Series ; and (iii) That the names of Annual Members who have not paid a subscription as a Member for five consecutive years shall, after an inquiry has been addressed to them, be withdrawn from the List of Members published annually and be placed on a Suspense List, without prejudice to their status as Members of the Association.

(II) The Committee, having provisionally revised, co-ordinated, and redrafted the existing Rules of the Association, ask for powers to complete their labours, under the authority of the General Committee.

(III) The Committee recommend that the Final Draft of the Rules, as amended, be published, with the sanction of the Council, in the Annual Report for 1906, and be submitted for adoption by the General Committee at the Meeting of the Association to be held in Leicester.

Signed, on behalf of the Committee,
 EDWARD BRABROOK.

The Council, in approving the terms of this report, recommend it to the General Committee for adoption.

RESEARCH COMMITTEES APPOINTED BY THE GENERAL COMMITTEE
AT THE YORK MEETING: AUGUST, 1906.

I. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of the Committee	Grants
SECTION A.—MATHEMATICS AND PHYSICS.		
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.	<p><i>Chairman.</i>—Lord Rayleigh. <i>Secretary.</i>—Dr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, and G. Carey Foster, Sir Oliver Lodge, Dr. A. Muirhead, Sir W. H. Preece, Professor A. Schuster, Dr. J. A. Fleming, Professor J. J. Thomson, Dr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. J. Rennie, Principal E. H. Griffiths, Sir A. W. Rücker, Professor H. L. Callendar, and Mr. G. Matthey.</p>	£ s. d. 50 0 0
Seismological Observations.	<p><i>Chairman.</i>—Professor J. W. Judd. <i>Secretary.</i>—Dr. J. Milne. Lord Kelvin, Dr. T. G. Bonney, Mr. C. V. Boys, Sir George Darwin, Mr. Horace Darwin, Major L. Darwin, Professor J. A. Ewing, Mr. M. H. Gray, Dr. R. T. Glazebrook, Professor C. G. Knott, Professor R. Meldola, Mr. R. D. Oldham, Professor J. Perry, Mr. W. E. Plummer, Professor J. H. Poynting, Mr. Clement Reid, Mr. Nelson Richardson, and Professor H. H. Turner.</p>	40 0 0
To co-operate with the Committee of the Falmouth Observatory in their Magnetic Observations.	<p><i>Chairman.</i>—Sir W. H. Preece. <i>Secretary.</i>—Dr. R. T. Glazebrook. Professor W. G. Adams, Captain Creak, Mr. W. L. Fox, Professor A. Schuster, Sir A. W. Rücker, and Dr. Charles Chree.</p>	40 0 0
To continue the Magnetic Survey of South Africa commenced by Professors Beattie and Morrison.	<p><i>Chairman.</i>—Sir David Gill. <i>Secretary.</i>—Professor J. C. Beattie. Mr. S. S. Hough, Professor Morrison, and Professor A. Schuster.</p>	25 7 6

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of the Committee	Grants
The further Tabulation of Bessel Functions.	<i>Chairman.</i> —Professor M. J. M. Hill. <i>Secretary.</i> —Dr. L. N. G. Filon. Professor Alfred Lodge.	£ s. d. 15 0 0
SECTION B.—CHEMISTRY.		
Preparing a new Series of Wave-length Tables of the Spectra of the Elements.	<i>Chairman.</i> —Sir H. E. Roscoe. <i>Secretary.</i> —Dr. Marshall Watts. Sir Norman Lockyer, Professors Sir J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, Sir W. de W. Abney, and Dr. W. E. Adeney.	10 0 0
The Study of Hydro-aromatic Substances.	<i>Chairman.</i> —Professor E. Divers. <i>Secretary.</i> —Dr. A. W. Crossley. Professor W. H. Perkin, Dr. M. O. Forster, and Dr. Le Sueur.	30 0 0
Dynamic Isomerism.	<i>Chairman.</i> —Professor H. E. Armstrong. <i>Secretary.</i> —Dr. T. M. Lowry. Professor Sydney Young, Dr. Desch, Dr. J. J. Dobbie, Dr. A. Lapworth, and Dr. M. O. Forster.	30 0 0
SECTION C.—GEOLOGY.		
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	<i>Chairman.</i> —Dr. J. E. Marr. <i>Secretary.</i> —Mr. P. F. Kendall. Dr. T. G. Bonney, Mr. C. E. De Rance, Professor W. J. Sollas, Mr. R. H. Tiddeman, Rev. S. N. Harrison, Dr. J. Horne, Mr. F. M. Burton, Mr. J. Lomas, Mr. A. R. Derryhouse, Mr. J. W. Stather, Mr. W. T. Tucker, and Mr. F. W. Harmer.	21 16 6
To study Life-zones in the British Carboniferous Rocks.	<i>Chairman.</i> —Dr. J. E. Marr. <i>Secretary.</i> —Dr. Wheelton Hind. Dr. F. A. Bather, Messrs. H. Bolton, G. C. Crick, A. H. Foord, and H. Fox, Professor E. J. Garwood, Dr. G. J. Hinde, Professor P. F. Kendall, Mr. R. Kidston, Mr. G. W. Lamplugh, Professor G. A. Lebour, Dr. B. N. Peach, Mr. A. Strahan, Mr. A. Vaughan, and Dr. H. Woodward.	12 7 7
To report upon the Fauna and Flora of the Trias of the British Isles.	<i>Chairman.</i> —Professor W. A. Herdman. <i>Secretary.</i> —Mr. J. Lomas. Professors W. W. Watts and P. F. Kendall, Messrs. H. C. Beasley, E. T. Newton, A. C. Seward, and W. A. E. Ussher, and Dr. A. Smith Woodward.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of the Committee	Grants
To investigate the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, and at various localities in the East Riding of Yorkshire.	<i>Chairman.</i> —Mr. G. W. Lamplugh. <i>Secretary.</i> —Mr. J. W. Stather. Dr. Tempest Anderson, Professor J. W. Carr, Rev. W. Lower Carter, Messrs. A. R. Dwerryhouse, F. W. Harmer, and J. H. Howarth, Rev. W. Johnson, and Messrs. P. F. Kendall, G. W. B. Macturk, E. T. Newton, H. M. Platnauer, Clement Reid, and T. Sheppard.	£ s. d. 25 19 0
To enable Mr. E. Greenly to complete his Researches on the Composition and Origin of the Crystalline Rocks of Anglesey.	<i>Chairman.</i> —Mr. A. Harker. <i>Secretary.</i> —Mr. E. Greenly. Mr. J. Lomas, Dr. C. A. Matley, and Professor K. J. P. Orton.	7 18 11
To enable Dr. A. Vaughan to continue his Researches on the Faunal Succession in the Carboniferous Limestone of the British Isles.	<i>Chairman.</i> —Professor J. W. Gregory. <i>Secretary.</i> —Dr. A. Vaughan. Dr. Wheelton Hind and Professor W. W. Watts.	15 0 0
To investigate and report on the Correlation and Age of South African Strata and on the question of a Uniform Stratigraphical Nomenclature.	<i>Chairman.</i> —Professor J. W. Gregory. <i>Secretary.</i> —Professor A. Young. Mr. W. Anderson, Professor R. Broom, Dr. G. S. Corstorphine, Mr. Walcot Gibson, Dr. F. H. Hatch, Mr. T. H. Holland, Mr. H. Kynaston, Dr. Molengraaf, Mr. A. J. C. Molyneux, Mr. A. W. Rogers, Mr. E. H. L. Schwarz, and Professor R. B. Young.	10 0 0
To investigate the Speeton Beds at Knapton.	<i>Chairman.</i> —Mr. J. F. Walker. <i>Secretary.</i> —Rev. W. Johnson. Messrs. H. M. Platnauer, T. Sheppard, and J. W. Stather.	10 0 0
SECTION D.—ZOOLOGY.		
To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	<i>Chairman.</i> —Professor S. J. Hickson. <i>Secretary.</i> —Rev. T. R. R. Stebbing. Professor E. Ray Lankester, Mr. A. Sedgwick, Professor W. C. McIntosh, and Mr. G. P. Bidder.	100 0 0
Compilation of an Index Generum et Specierum Animalium.	<i>Chairman.</i> —Dr. H. Woodward. <i>Secretary.</i> —Dr. F. A. Bather. Dr. P. L. Sclater, Rev. T. R. R. Stebbing, Mr. W. E. Hoyle, the Hon. Walter Rothschild, and Lord Walsingham.	75 0 0
To enable Mr. J. W. Jenkinson to continue his Researches on the Influence of Salt and other Solutions on the Development of the Frog.	<i>Chairman.</i> —Professor G. C. Bourne. <i>Secretary.</i> —Mr. J. W. Jenkinson. Professor S. J. Hickson.	5 14 6

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of the Committee	Grants
To enable Dr. F. W. Gamble and Dr. F. W. Keeble to conduct Researches on the Relation between Respiratory Phenomena and Colour Changes in Animals.	<i>Chairman.</i> —Professor S. J. Hickson. <i>Secretary.</i> —Dr. F. W. Gamble, Dr. Hoyle and Dr. F. W. Keeble.	£ s. d. 11 2 0
To enable Dr. H. W. Marett Tims to conduct experiments with regard to the effect of the Sera and Antisera on the Development of the Sexual Cells.	<i>Chairman.</i> —Mr. J. J. Lister. <i>Secretary.</i> —Dr. H. W. Marett Tims, Mr. J. Stanley Gardiner and Mr. G. H. F. Nuttall.	5 0 0
SECTION E.—GEOGRAPHY.		
The Quantity and Composition of Rainfall, and of Lake and River Discharge.	<i>Chairman.</i> —Sir John Murray. <i>Secretaries.</i> —Professor A. B. Macallum and Dr. A. J. Herbertson, Sir B. Baker, Professor W. M. Davis, Professor P. F. Frankland, Mr. A. D. Hall, Mr. N. F. Mackenzie, Mr. E. H. V. Melville, Dr. H. R. Mill, Professor A. Penck, Mr. A. Strahan, and Mr. W. Whitaker.	10 0 0
The continued Investigation of the Oscillations of the Level of the Land in the Mediterranean Basin.	<i>Chairman.</i> —Mr. D. G. Hogarth. <i>Secretary.</i> —Mr. R. T. Günther. Drs. T. G. Bonney, F. H. Guille- nard, J. S. Keltie, and H. R. Mill.	50 0 0
SECTION F.—ECONOMIC SCIENCE AND STATISTICS.		
The Accuracy and Comparability of British and Foreign Statistics of International Trade.	<i>Chairman.</i> —Dr. E. Cannan. <i>Secretary.</i> —Mr. H. O. Meredith, Mr. W. G. S. Adams, Mr. A. L. Bowley, Professor S. J. Chapman, Professor H. E. S. Fremantle, Sir R. Giffen, and Mr. B. Seeböhm Rowntree.	15 0 0
The Amount of Gold Coinage in Circulation in the United Kingdom.	<i>Chairman.</i> —Mr. R. H. Inglis Palgrave. <i>Secretary.</i> —Mr. H. Stanley Jevons. Messrs. A. L. Bowley and D. H. Macgregor.	10 0 0
SECTION H.—ANTHROPOLOGY.		
To conduct Archæological and Ethnological Researches in Crete.	<i>Chairman.</i> —Sir John Evans. <i>Secretary.</i> —Mr. J. L. Myres, Mr. R. C. Bosanquet, Dr. A. J. Evans, Mr. D. G. Hogarth, Professor A. Macalister, and Professor W. Ridgeway.	100 0 0
To investigate the Lake Village at Glastonbury, and to report on the best method of publication of the result.	<i>Chairman.</i> —Dr. R. Munro. <i>Secretary.</i> —Professor W. Boyd Dawkins. Sir John Evans and Messrs. Arthur J. Evans, O. H. Read, H. Balfour, and A. Bulleid.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of the Committee	Grants
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	<p><i>Chairman.</i>—Professor W. Boyd Dawkins.</p> <p><i>Secretary.</i>—Mr. J. L. Myres.</p> <p>Sir Edward Brabrook, Mr. T. Ashby, Professor R. C. Bosanquet, and Professor W. Ridgeway.</p>	<p>£ s. d.</p> <p>15 0 0</p>
To organise Anthropometric Investigation in the British Isles.	<p><i>Chairman.</i>—Professor D. J. Cunningham.</p> <p><i>Secretary.</i>—Mr. J. Gray.</p> <p>Dr. A. C. Haddon, Dr. C. S. Myers, Mr. J. L. Myres, Professor A. F. Dixon, Mr. E. N. Fallaize, Mr. Randall-MacIver, Professor J. Symington, Dr. Waterston, Sir Edward Brabrook, Dr. T. H. Bryce, Mr. W. H. L. Duckworth, Mr. G. L. Gomme, Major T. McCulloch, Dr. F. C. Shruballs, Professor G. D. Thane, Mr. J. F. Tocher, Dr. W. McDougall, Mr. W. M. Heller, Mr. C. M. Stuart, and Professor M. E. Sadler.</p>	<p>17 17 3</p>
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	<p><i>Chairman.</i>—Mr. C. H. Read.</p> <p><i>Secretary.</i>—Mr. H. Balfour.</p> <p>Sir John Evans, Dr. J. G. Garson, Dr. A. J. Evans, Dr. R. Munro, Professor Boyd Dawkins, and Mr. A. L. Lewis</p>	<p>3 0 0</p>
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	<p><i>Chairman.</i>—Mr. C. H. Read.</p> <p><i>Secretary.</i>—Mr. H. S. Kingsford.</p> <p>Dr. T. Ashby, jun., Dr. G. A. Auden, Mr. H. Balfour, Mr. E. N. Fallaize, Dr. A. C. Haddon, Mr. E. S. Hartland, Mr. E. Heawood, Mr. J. L. Myres, and Professor Flinders Petrie.</p>	<p>3 3 6</p>
SECTION I.—PHYSIOLOGY.		
To enable Professor Starling, Professor Brodie, Dr. Hopkins, Mr. Fletcher, Mr. Barcroft, and others to determine the 'Metabolic Balance-Sheet' of the Individual Tissues.	<p><i>Chairman.</i>—Professor Gotch.</p> <p><i>Secretary.</i>—Mr. J. Barcroft.</p> <p>Sir Michael Foster and Professor Starling.</p>	<p>45 0 0</p>
The Ductless Glands.	<p><i>Chairman.</i>—Professor Schäfer.</p> <p><i>Secretary.</i>—Professor Swale Vincent.</p> <p>Professor A. B. Macallum and Dr. L. E. Shore.</p>	<p>25 0 0</p>

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of the Committee	Grants
The Effect of Climate upon Health and Disease.	<i>Chairman.</i> —Sir T. Lauder Brunton. <i>Secretary.</i> —Mr. J. Barcroft. Colonel D. Bruce, Dr. A. Buchan, Dr. F. Campbell, Sir Kendal Franks, Professor J. G. McKendrick, Sir A. Mitchell, Dr. W. C. F. Murray, Dr. Porter, Professor Sims Woodhead, Dr. A. J. Wright, and the Heads of the Tropical Schools of Liverpool and London.	£ s. d. 55 0 0
SECTION K.—BOTANY.		
To carry out the scheme for the Registration of Negatives of Botanical Photographs.	<i>Chairman.</i> —Professor F.W. Oliver. <i>Secretary.</i> —Professor F. E. Weiss. Dr. W. G. Smith, Mr. A. G. Tansley, Dr. T. W. Woodhead, and Professor R. H. Yapp.	5 0 0
Experimental Studies in the Physiology of Heredity.	<i>Chairman.</i> —Mr. Francis Darwin. <i>Secretary.</i> —Mr. H. Wager. Professor J. B. Farmer and Mr. R. P. Gregory.	30 0 0
The Structure of Fossil Plants.	<i>Chairman.</i> —Dr. D. H. Scott. <i>Secretary.</i> —Professor F.W. Oliver. Messrs. E. Newell Arber and A. C. Seward and Professor F. E. Weiss.	5 0 0
Research on South African Cycads, and on Welwitschia.	<i>Chairman.</i> —Mr. A. C. Seward. <i>Secretary.</i> —Mr. R. P. Gregory. Dr. D. H. Scott and Dr. W. H. Lang.	35 0 0
The Peat Moss Deposits in the Cross Fell, Caithness, and Isle of Man Districts.	<i>Chairman.</i> —Professor R.J. Harvey Gibson. <i>Secretary.</i> —Professor R. H. Yapp. Professor J. R. Green and Mr. Clement Reid.	7 5 7
Studies on Marsh Vegetation.	<i>Chairman.</i> —Dr. F. F. Blackman. <i>Secretary.</i> —Mr. A. C. Seward. Messrs. A. W. Hill and A. G. Tansley.	15 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of the Committee	Grants
SECTION L.—EDUCATIONAL SCIENCE.		
To report upon the Course of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.	<i>Chairman.</i> —Sir Philip Magnus. <i>Secretary.</i> —Mr. W. M. Heller. Sir W. de W. Abney, Mr. R. H. Adie, Professor H. E. Armstrong, Miss A. J. Cooper, Miss L. J. Clarke, Mr. George Fletcher, Professor R. A. Gregory, Principal Griffiths, Mr. A. D. Hall, Dr. A. J. Herbertson, Dr. C. W. Kimmins, Professor J. Perry, Mrs. W. N. Shaw, Professor A. Smithells, Dr. Lloyd Snape, Principal Reichel, Mr. H. Richardson, Miss Edna Walter, and Professor W. W. Watts.	£ s. d. 10 0 0
The Conditions of Health essential to the carrying on of the work of instruction in schools.	<i>Chairman.</i> —Professor Sherrington. <i>Secretary.</i> —Mr. E. White Wallis. Sir Edward Brabrook, Dr. C. W. Kimmins, Professor L. C. Miall, Miss A. J. Cooper, and Dr. Ethel Williams.	5 0 0
CORRESPONDING SOCIETIES.		
Corresponding Societies Committee for the preparation of their Report.	<i>Chairman.</i> —Mr. W. Whitaker. <i>Secretary.</i> —Mr. F. W. Rudler. Rev. J. O. Bevan, Sir Edward Brabrook, Dr. H. T. Brown, Dr. Vaughan Cornish, Dr. J. G. Garson, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Professor R. Meldola, Dr. H. R. Mill, Mr. C. H. Read, Rev. T. R. R. Stebbing, Professor W. W. Watts, and the General Officers of the Association.	20 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of the Committee
SECTION A.—MATHEMATICS AND PHYSICS.	
To co-operate with the Royal Meteorological Society in the Investigation of the Upper Atmosphere by means of Kites.	<i>Chairman.</i> —Dr. W. N. Shaw. <i>Secretary.</i> —Mr. W. H. Dines. Mr. P. Y. Alexander, Mr. D. Archibald, Mr. C. Vernon Boys, Dr. A. Buchan, Dr. R. T. Glazebrook, Dr. H. R. Mill, Dr. A. Schuster, and Dr. W. Watson.

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

Subject for Investigation, or Purpose	Members of the Committee
To co-operate with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	<i>Chairman.</i> —Lord McLaren. <i>Secretary.</i> —Professor Crum Brown. Sir John Murray, Dr. A. Buchan, Professor F. W. Dyson, and Mr. Omond.
The Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water.	<i>Chairman and Secretary.</i> —Professor H. L. Callendar. Lord Kelvin, Sir Archibald Geikie, Professor Edward Hull, Professor A. S. Herschel, Professor G. A. Lebour, Professor C. H. Lees, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. Edward Wethered, Mr. A. Strahan, Professor Michie Smith, and Mr. B. H. Brough.
The Consideration of the Teaching of Elementary Mechanics, and the Improvement which might be effected in such Teaching.	<i>Chairman.</i> —Professor Horace Lamb. <i>Secretary.</i> —Professor J. Perry. Mr. C. Vernon Boys, Professors Chrystal, Ewing, G. A. Gibson, and Greenhill, Principal Griffiths, Professor Henrici, Dr. E. W. Hobson, Mr. C. S. Jackson, Sir Oliver Lodge, Professors Love, Minchin, Schuster, and A. M. Worthington, and Mr. A. W. Siddons.
That Miss Hardcastle be requested continue her Report on the present state of the Theory of Point-groups.	

SECTION B.—CHEMISTRY.

The Study of Isomorphous Sulphonic Derivatives of Benzene.	<i>Chairman.</i> —Professor H. A. Miers. <i>Secretary.</i> —Professor H. E. Armstrong. Professors W. P. Wynne and W. J. Pope.
The Transformation of Aromatic Nitramines and allied substances, and its relation to Substitution in Benzene Derivatives.	<i>Chairman.</i> —Professor F. S. Kipping. <i>Secretary.</i> —Professor K. J. P. Orton. Dr. S. Ruhemann, Dr. A. Lapworth, and Dr. J. T. Hewitt.

SECTION C.—GEOLOGY.

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	<i>Chairman.</i> —Professor J. Geikie. <i>Secretary.</i> —Professor W. W. Watts. Dr. T. G. Bonney, Dr. T. Anderson, Professors E. J. Garwood and S. H. Reynolds, and Messrs. A. S. Reid, W. Gray, H. B. Woodward, R. Kidston, J. J. H. Teall, H. Coates, C. V. Crook, G. Bingley, R. Welch, and W. J. Harrison.
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2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of the Committee
To record and determine the Exact Significance of Local Terms applied in the British Isles to Topographical and Geological Objects.	<p><i>Chairman.</i>—Mr. Douglas W. Freshfield. <i>Secretary.</i>—Mr. W. G. Fearnside.</p> <p>Lord Avebury, Mr. C. T. Clough, Professor E. J. Garwood, Mr. E. Heawood, Dr. A. J. Herbertson, Col. D. A. Johnston, Mr. O. T. Jones, Dr. J. S. Keltie, Mr. G. W. Lamplugh, Mr. H. J. Mackinder, Dr. E. J. Marr, Dr. H. R. Mill, Mr. H. Yule Oldham, Dr. B. N. Peach, Professor W. W. Watts, and Mr. H. B. Woodward.</p>
To enable Mr. T. N. Leslie to continue his researches into the Fossil Flora of the Transvaal.	<p><i>Chairman.</i>—Professor J. W. Gregory. <i>Secretary.</i>—Mr. A. C. Seward. Mr. T. N. Leslie.</p>
To investigate the Pre-Devonian Rocks of the Mendips.	<p><i>Chairman.</i>—Mr. H. B. Woodward. <i>Secretary.</i>—Professor S. H. Reynolds. Dr. C. Lloyd Morgan and Rev. H. H. Winwood.</p>

SECTION D.—ZOOLOGY.

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.	<p><i>Chairman.</i>—Professor A. Newton. <i>Secretary.</i>—Dr. David Sharp. Professor S. J. Hickson, Dr. P. L. Sclater, Mr. F. Du Cane Godman, and Mr. Edgar A. Smith.</p>
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology or Zoologists, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the Organisation.	<p><i>Chairman.</i>—Professor E. Ray Lankester. <i>Secretary.</i>—Professor S. J. Hickson. Professors G. C. Bourne, T. W. Bridge, J. Cossar Ewart, M. Hartog, W. A. Herdman, and J. Graham Kerr, Mr. O. H. Latter, Professor Minchin, Dr. P. C. Mitchell, Professor C. Lloyd Morgan, Professor E. B. Poulton, Mr. A. Sedgwick, Mr. A. E. Shipley, and Rev. T. R. R. Stebbing.</p>
To nominate competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	<p><i>Chairman and Secretary.</i>—Professor A. Dendy. Professor E. Ray Lankester, Mr. A. Sedgwick, and Professor Sydney H. Vines.</p>
To carry on an Expedition to investigate the Indian Ocean between India and South Africa in view of a possible land connection, to examine the deep submerged banks, the Nazareth and Saza de Malha, and also the distribution of Marine Animals.	<p><i>Chairman.</i>—Sir John Murray. <i>Secretary.</i>—Mr. J. Stanley Gardiner. Captain E. W. Creak, Admiral A. Mostyn Field, Professors W. A. Herdman, S. J. Hickson, and J. W. Judd, Mr. J. J. Lister, and Dr. H. R. Mill.</p>

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

Subject for Investigation, or Purpose	Members of the Committee
SECTION H.—ANTHROPOLOGY.	
To conduct Anthropometric Investigations among the Native Troops of the Egyptian Army.	<i>Chairman.</i> —Professor A. Macalister. <i>Secretary.</i> —Dr. C. S. Myers. Sir John Evans and Professor D. J. Cunningham.
To explore Ancient Ruins in Portuguese East Africa.	<i>Chairman.</i> —Dr. A. C. Haddon. <i>Secretary.</i> —Mr. H. Balfour. Messrs. E. Sidney Hartland and D. Randall-MacIver.
To explore the 'Red Hills' of the East Coast Salt Marshes.	<i>Chairman.</i> —Professor R. Meldola. <i>Secretary.</i> —Mr. F. W. Rudler. Messrs. C. H. Read and T. V. Holmes.
To report on the best means of Registering and Classifying systematically Megalithic Remains in the British Isles.	<i>Chairman.</i> —Professor W. Ridgeway. <i>Secretary.</i> —Dr. G. A. Auden. Messrs. J. L. Myres and G. L. Gomme.
SECTION L.—EDUCATIONAL SCIENCE.	
The Training of Teachers.	<i>Chairman.</i> — <i>Secretary.</i> —Mr. J. L. Holland. Mr. R. H. Adie, Professor H. E. Armstrong, Mr. Oscar Browning, Miss A. J. Cooper, Mr. Ernest Gray, and Dr. H. B. Gray.
To consider and to advise as to the Curricula of Secondary Schools; in the first instance, the Curricula of Boys' Schools.	<i>Chairman.</i> —Sir Oliver Lodge. <i>Secretary.</i> —Mr. C. M. Stuart. Mr. T. E. Page, Professors M. E. Sadler, H. E. Armstrong, and J. Perry, Sir Philip Magnus, Principal Griffiths, Dr. Gray, Professor H. A. Miers, Mr. A. E. Shipley, Professor J. Findlay, and Sir William Huggins.

Communications ordered to be printed in extenso.

On the Evolution of the Elements. By F. Soddy.

On the Production of Prussic Acid in Plants. By Professor W. R. Dunstan and Dr. Henry.

On the Occurrence of Prussic Acid in Plants. By Dr. Greshoff.

On the present position of the Chemistry of Rubber. By S. S. Pickles.

On the present position of the Chemistry of Gums. By H. H. Robinson.

On the Hydrolysis of Sugars. By R. J. Caldwell.

On Melanism in Lepidoptera. By G. T. Porritt.

The Work of the Engineering Standards Committee. By Sir John Wolfe-Barry, R.C.B.

An Application of Stream-line Apparatus to the Determination of the Dissection and Approximate Magnitude of the Principal Stresses in certain portions of the Structure of Ships. By M. J. Smith.

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

From Section A.

That, in the opinion of the Committee of Section A, it is highly desirable that Sir William Hamilton's Memoirs on Dynamics, on Systems of Rays, and other Memoirs on Pure and Applied Mathematics, should be republished in accessible form; and that this Resolution, if approved by the Council, be communicated to the Royal Irish Academy.

From Section H.

That the Council of the British Association be asked to impress upon his Majesty's Government the desirability of appointing an Inspector of Ancient Monuments, fully qualified to perform the duties of his office, with full powers under the Act, and with instructions to report periodically on his work with a view to publication.

Synopsis of Grants of Money appropriated for Scientific Purposes by the General Committee at the York Meeting, August 1906. The Names of Members entitled to call on the General Treasurer for the Grants are prefixed to the respective Research Committees.

Mathematical and Physical Science.

	£	s.	d.
*Rayleigh, Lord—Electrical Standards	50	0	0
*Judd, Professor J. W.—Seismological Observations	40	0	0
*Preece, Sir W. H.—Magnetic Observations at Falmouth ...	40	0	0
*Gill, Sir D.—Magnetic Survey of South Africa	25	7	6
Hill, Professor H. J. M.—Further Tabulation of Bessel Functions	15	0	0

Chemistry.

*Roscoe, Sir H. E.—Wave-length Tables of Spectra	10	0	0
*Divers, Professor E.—Study of Hydro-Aromatic Substances	30	0	0
*Armstrong, Professor H. E.—Dynamic Isomerism	30	0	0

Geology.

*Marr, Dr. J. E.—Erratic Blocks.....	21	16	6
*Marr, Dr. J. E.—Life-zones in British Carboniferous Rocks	12	7	7
*Herdman, Professor W. A.—Fauna and Flora of British Trias	10	0	0
*Lamplugh, G. W.—Fossiliferous Drift Deposits	25	19	0
*Harker, Dr. A.—The Crystalline Rocks of Anglesey	7	18	11
*Gregory, Professor J. W.—Faunal Succession in the Car- boniferous Limestone of the British Isles	15	0	0
*Gregory, Professor J. W.—Correlation and Age of South African Strata, &c.	10	0	0
Walker, J. F.—Investigation of the Speeton Beds at Knapton	10	0	0

Zoology.

*Woodward, Dr. H.—Index Animalium	75	0	0
*Hickson, Professor S. J.—Table at the Zoological Station at Naples	100	0	0
*Bourne, Professor G. C.—Development of the Frog.....	5	14	6
*Hickson, Professor S. J.—Respiratory Phenomena and Colour Changes in Animals	11	2	0
*Lister, J. J.—Experiments on the Development of the Sexual Cells	5	0	0

Geography.

*Hogarth, D. G.—Oscillations of the Land Level in the Mediterranean Basin	50	0	0
*Murray, Sir J.—Rainfall and Lake and River Discharge ...	10	0	0
Carried forward	£610	6	0

* Reappointed.

	£	s.	d.
Brought forward.....	610	6	0

Economic Science and Statistics.

*Cannan, Dr. E.—International Trade Statistics	15	0	0
Palgrave, R. H. Inglis.—Gold Coinage in Circulation in the United Kingdom.....	10	0	0

Anthropology.

*Evans, Sir John.—Excavations in Crete	100	0	0
*Munro, Dr. R.—Glastonbury Lake Village	30	0	0
*Dawkins, Professor W. Boyd.—Excavations on Roman Sites in Britain	15	0	0
*Cunningham, Professor D. J.—Anthropometric Investigations	17	17	3
*Read, C. H.—Age of Stone Circles.....	3	0	0
*Read, C. H.—Anthropological Photographs	3	3	6

Physiology.

*Gotch, Professor—Metabolism of Individual Tissues	45	0	0
*Schäfer, Professor—The Ductless Glands	25	0	0
*Brunton, Sir T. Lauder.—Effect of Climate upon Health and Disease	55	0	0

Botany.

*Darwin, Francis.—Physiology of Heredity	30	0	0
*Scott, Dr. D. H.—Structure of Fossil Plants	5	0	0
*Seward, A. C.—South African Cycads, &c.	35	0	0
*Oliver, Professor F. W.—Botanical Photographs	5	0	0
*Gibson, Professor Harvey.—Peat Moss Deposits	7	5	7
Blackman, Dr. F. F.—Marsh Vegetation	15	0	0

Educational Science.

*Magnus, Sir P.—Studies suitable for Elementary Schools ...	10	0	0
*Sherrington, Professor.—Conditions of Health in Schools ...	5	0	0

Corresponding Societies Committee.

*Whitaker, W.—For Preparation of Report	20	0	0
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£1,061 12 4

* Reappointed.

Annual Meetings, 1907, 1908, and 1909.

The Annual Meeting of the Association in 1907 will be held at Leicester, commencing July 31; in 1908 at Dublin; and in 1909 at Winnipeg.

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

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

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	
	<u>£1235</u>	<u>10</u>	<u>11</u>	

1842.		£	s.	d.
Dynamometric Instruments..	113	11	2	
Anoplura Britannæ	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	

	£	s.	d.
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
	<u>£1449</u>	<u>17</u>	<u>8</u>

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.	1845.	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0	Publication of the British Association Catalogue of Stars	351	14	6
Additional Experiments on the Forms of Vessels	100	0	0	Meteorological Observations at Inverness	30	18	11
Reduction of Experiments on the Forms of Vessels	100	0	0	Magnetic and Meteorological Co-operation	16	16	8
Morin's Instrument and Constant Indicator	69	14	10	Meteorological Instruments at Edinburgh.....	18	11	9
Experiments on the Strength of Materials	60	0	0	Reduction of Anemometrical Observations at Plymouth	25	0	0
	£1565	10	2	Electrical Experiments at Kew Observatory	43	17	8
1844.				Maintaining the Establishment at Kew Observatory	149	15	0
Meteorological Observations at Kingussie and Inverness	12	0	0	For Kreil's Barometograph	25	0	0
Completing Observations at Plymouth	35	0	0	Gases from Iron Furnaces...	50	0	0
Magnetic and Meteorological Co-operation	25	8	4	The Actinograph	15	0	0
Publication of the British Association Catalogue of Stars	35	0	0	Microscopic Structure of Shells	20	0	0
Observations on Tides on the East Coast of Scotland ...	100	0	0	Exotic Anoplura	1843	10	0
Revision of the Nomenclature of Stars	1842	2	9	Vitality of Seeds	1843	2	0
Maintaining the Establishment at Kew Observatory	117	17	3	Vitality of Seeds	1844	7	0
Instruments for Kew Observatory	56	7	3	Marine Zoology of Cornwall .	10	0	0
Influence of Light on Plants	10	0	0	Physiological Action of Medicines	20	0	0
Subterraneous Temperature in Ireland	5	0	0	Statistics of Sickness and Mortality in York.....	20	0	0
Coloured Drawings of Railway Sections	15	17	6	Earthquake Shocks	1843	15	14
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0		£831	9	9
Registering the Shocks of Earthquakes	1842	23	11	1846.			
Structure of Fossil Shells ...	20	0	0	British Association Catalogue of Stars	1844	211	15
Radiata and Mollusca of the Ægean and Red Seas	1842	100	0	Fossil Fishes of the London Clay.....	100	0	0
Geographical Distributions of Marine Zoology.....	1842	0	10	Computation of the Gaussian Constants for 1829	50	0	0
Marine Zoology of Devon and Cornwall	10	0	0	Maintaining the Establishment at Kew Observatory	146	16	7
Marine Zoology of Corfu.....	10	0	0	Strength of Materials	60	0	0
Experiments on the Vitality of Seeds	9	0	0	Researches in Asphyxia	6	16	2
Experiments on the Vitality of Seeds	1842	8	7	Examination of Fossil Shells	10	0	0
Exotic Anoplura	15	0	0	Vitality of Seeds	1844	2	15
Strength of Materials	100	0	0	Vitality of Seeds	1845	7	12
Completing Experiments on the Forms of Ships	100	0	0	Marine Zoology of Cornwall	10	0	0
Inquiries into Asphyxia	10	0	0	Marine Zoology of Britain ...	10	0	0
Investigations on the Internal Constitution of Metals.....	50	0	0	Exotic Anoplura	1844	25	0
Constant Indicator and Morin's Instrument	1842	10	0	Expenses attending Anemometers.....	11	7	6
	£981	12	8	Anemometers' Repairs... ..	2	3	6
				Atmospheric Waves	3	3	3
				Captive Balloons	1844	8	19
				Varieties of the Human Race	1844	7	6
				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
	<u>£208</u>	<u>5</u>	<u>4</u>

1848.	£	s.	d.
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
	<u>£275</u>	<u>1</u>	<u>8</u>

1849.	£	s.	d.
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
	<u>£159</u>	<u>19</u>	<u>6</u>

1850.	£	s.	d.
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
	<u>£345</u>	<u>18</u>	<u>0</u>

1851.	£	s.	d.
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
	<u>£391</u>	<u>9</u>	<u>7</u>

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
	<u>£304</u>	<u>6</u>	<u>7</u>

1853.	£	s.	d.
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
	<u>£205</u>	<u>0</u>	<u>0</u>

1854.	£	s.	d.
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
	<u>£380</u>	<u>19</u>	<u>7</u>

1855.	£	s.	d.
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
	<u>£480</u>	<u>16</u>	<u>4</u>

1856.	£	s.	d.	
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
	<u>£734</u>	<u>13</u>	<u>9</u>

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
	<u>£507</u>	<u>15</u>	<u>4</u>

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
	<u>£618</u>	<u>18</u>	<u>2</u>

1859.

Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0

	£	s.	d.
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
	<u>£684</u>	<u>11</u>	<u>1</u>

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
	<u>£766</u>	<u>19</u>	<u>6</u>

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	} 72	0	0
1861.....£22 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
	<u>£1111</u>	<u>5</u>	<u>10</u>

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	
	<u>£1293</u>	<u>16</u>	<u>6</u>	

1863.

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

	£	s.	d.
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	<u>£1608</u>	<u>3</u>	<u>10</u>

1864.

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
	<u>£1289</u>	<u>15</u>	<u>8</u>

1865.

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
	<u>£1591</u>	<u>7</u>	<u>10</u>

1866.

1868.

1866.			1868.		
	£	s. d.		£	s. d.
Maintaining the Establishment at Kew Observatory..	600	0 0	Maintaining the Establishment at Kew Observatory..	600	0 0
Lunar Committee.....	64	13 4	Lunar Committee.....	120	0 0
Balloon Committee.....	50	0 0	Metrical Committee.....	50	0 0
Metrical Committee.....	50	0 0	Zoological Record.....	100	0 0
British Rainfall.....	50	0 0	Kent's Hole Explorations ...	150	0 0
Kilkenny Coal Fields.....	16	0 0	Steamship Performances.....	100	0 0
Alum Bay Fossil Leaf-bed ...	15	0 0	British Rainfall.....	50	0 0
Luminous Meteors.....	50	0 0	Luminous Meteors.....	50	0 0
Lingula Flags Excavation ...	20	0 0	Organic Acids.....	60	0 0
Chemical Constitution of Cast Iron.....	50	0 0	Fossil Crustacea.....	25	0 0
Amyl Compounds.....	25	0 0	Methyl Series.....	25	0 0
Electrical Standards.....	100	0 0	Mercury and Bile.....	25	0 0
Malta Caves Exploration.....	30	0 0	Organic Remains in Lime- stone Rocks.....	25	0 0
Kent's Hole Exploration.....	200	0 0	Scottish Earthquakes.....	20	0 0
Marine Fauna, &c., Devon and Cornwall.....	25	0 0	Fauna, Devon and Cornwall..	30	0 0
Dredging Aberdeenshire Coast	25	0 0	British Fossil Corals.....	50	0 0
Dredging Hebrides Coast ...	50	0 0	Bagshot Leaf-beds.....	50	0 0
Dredging the Mersey.....	5	0 0	Greenland Explorations.....	100	0 0
Resistance of Floating Bodies in Water.....	50	0 0	Fossil Flora.....	25	0 0
Polycyanides of Organic Rad- icals.....	29	0 0	Tidal Observations.....	100	0 0
Rigor Mortis.....	10	0 0	Underground Temperature... Spectroscopic Investigations of Animal Substances.....	50	0 0
Irish Annelida.....	15	0 0	Secondary Reptiles, &c.....	30	0 0
Catalogue of Crania.....	50	0 0	British Marine Invertebrate Fauna.....	100	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		£1940	0 0

1867.

1869.

1867.			1869.		
	£	s. d.		£	s. d.
Maintaining the Establishment at Kew Observatory..	600	0 0	Maintaining the Establishment at Kew Observatory..	600	0 0
Meteorological Instruments, Palestine.....	50	0 0	Lunar Committee.....	50	0 0
Lunar Committee.....	120	0 0	Metrical Committee.....	25	0 0
Metrical Committee.....	30	0 0	Zoological Record.....	100	0 0
Kent's Hole Explorations ...	100	0 0	Committee on Gases in Deep- well Water.....	25	0 0
Palestine Explorations.....	50	0 0	British Rainfall.....	50	0 0
Insect Fauna, Palestine.....	30	0 0	Thermal Conductivity of Iron, &c.....	30	0 0
British Rainfall.....	50	0 0	Kent's Hole Explorations.....	150	0 0
Kilkenny Coal Fields.....	25	0 0	Steamship Performances.....	30	0 0
Alum Bay Fossil Leaf-bed ...	25	0 0	Chemical Constitution of Cast Iron.....	80	0 0
Luminous Meteors.....	50	0 0	Iron and Steel Manufacture	100	0 0
Bournemouth, &c., Leaf-beds	30	0 0	Methyl Series.....	30	0 0
Dredging Shetland.....	75	0 0	Organic Remains in Lime- stone Rocks.....	10	0 0
Steamship Reports Condensa- tion.....	100	0 0	Earthquakes in Scotland.....	10	0 0
Electrical Standards.....	100	0 0	British Fossil Corals.....	50	0 0
Ethyl and Methyl Series.....	25	0 0	Bagshot Leaf-beds.....	30	0 0
Fossil Crustacea.....	25	0 0	Fossil Flora.....	25	0 0
Sound under Water.....	24	4 0	Tidal Observations.....	100	0 0
North Greenland Fauna.....	75	0 0	Underground Temperature... Spectroscopic Investigations of Animal Substances.....	30	0 0
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1870.

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
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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
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1871.

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Metrical Committee.....	25	0	0
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Tidal Observation	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

1872.

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Exploration of Moab.....	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration..	100	0	0
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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
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1873.

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
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1874.		£	s.	d.
Zoological Record.....	100	0	0	
Chemistry Record.....	100	0	0	
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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	
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Physiological Action of Light	20	0	0	
Trades Unions	25	0	0	
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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	
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Palestine Exploration	100	0	0	
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Geological Record.....	100	0	0
Kent's Cavern Exploration...	100	0	0
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Geological Record.....	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
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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
	<u>£1417</u>	<u>0</u>	<u>11</u>

1890.	£	s.	d.
Electrical Standards.....	12	17	0
Electrolysis	5	0	0
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Pellian Equation Tables	15	0	0
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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 Perade- niya	25	0	0

	£	s.	d.
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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
	<u>£799</u>	<u>16</u>	<u>8</u>

1891.

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
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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
	<u>£1029</u>	<u>10</u>	<u>0</u>

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
	<u>£864</u>	<u>10</u>	<u>0</u>

1893.

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 Fal-mouth 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 Hydro- graphy 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
	<u>£907</u>	<u>15</u>	<u>6</u>

1894.

Electrical Standards.....	25	0	0
Photographs of Meteorological Phenomena.....	10	0	0
Tables of Mathematical Func- tions	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 Phyllopora	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-tre- mors	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 Glaston- bury.....	40	0	0
Anthropometrical Measure- ments in Schools	5	0	0
Mental and Physical Condi- tion of Children.....	20	0	0
Corresponding Societies	25	0	0
	<u>£583</u>	<u>15</u>	<u>6</u>

	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 Obser- vations made at Falmouth Observatory	50	0	0
Comparison of Magnetic Stan- dards	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 Deri- vatives.....	30	0	0
Electrolytic Quantitative An- alysis	30	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopora	5	0	0
Photographs of Geological In- terest	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 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 Labo- ratory, 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 Measure- ments 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
	<u>£977</u>	<u>15</u>	<u>5</u>

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
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Erratic Blocks	10	0	0
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Table at the Biological Laboratory, Plymouth	15	0	0
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Lake Village at Glastonbury .	30	0	0
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Corresponding Societies Committee	30	0	0
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1897.	£	s.	d.
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Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals.....	10	0	0
Electrolysis and Electro-chemistry	50	0	0
Electrolytic Quantitative Analysis.....	10	0	0
Isomeric Naphthalene Derivatives.....	50	0	0
Erratic Blocks	10	0	0
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Zoological Bibliography and Publication.....	5	0	0
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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
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Corresponding Societies Committee	25	0	0
	£1059	10	8

1898.	£	s.	d.
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
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Climatology of Tropical Africa	10	0	0
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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
	<u>£1212</u>	<u>0</u>	<u>0</u>

1899.

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
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Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium.....	100	0	0
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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
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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
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Physiological Effects of Peptone.....	30	0	0
Electrical Changes accompanying Discharge of Respiratory Centres.....	20	0	0
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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
	<u>£1430</u>	<u>14</u>	<u>2</u>

1900.

Electrical Standards.....	25	0	0
Seismological Observations...	60	0	0
Radiation in a Magnetic Field	25	0	0
Meteorological Observatory at Montreal.....	20	0	0
Tables of Mathematical Functions	75	0	0
Relation between Absorption Spectra and Constitution of Organic Bodies.....	30	0	0
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Electrolytic Quantitative Analysis	5	0	0

	£	s.	d.
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Pleistocene Fauna and Flora in Canada	10	0	0
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Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium.....	50	0	0
Migration of Birds	15	0	0
Plankton and Physical Conditions of the English Channel	40	0	0
Zoology of the Sandwich Islands	100	0	0
Coral Reefs of the Indian Region	30	0	0
Physical and Chemical Constants of Sea-Water	100	0	0
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Ethnological Survey of Canada	50	0	0
New Edition of 'Anthropological Notes and Queries'	40	0	0
Photographs of Anthropological Interest	10	0	0
Mental and Physical Condition of Children in Schools	5	0	0
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Physiological Effects of Peptone	20	0	0
Comparative Histology of Suprarenal Capsules.....	20	0	0
Comparative Histology of Cerebral Cortex.....	5	0	0
Electrical Changes in Mammalian Nerves	20	0	0
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Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Com.	20	0	0
	£1072	10	0

1901.

Electrical Standards	45	0	0
Seismological Observations...	75	0	0
Wave-length Tables.....	4	14	0
Isomorphous Sulphonic Derivatives of Benzene	35	0	0

	£	s.	d.
Life-zones in British Carboniferous Rocks	20	0	0
Underground Water of North-west Yorkshire	50	0	0
Exploration of Irish Caves...	15	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.....	75	0	0
Migration of Birds	10	0	0
Terrestrial Surface Waves ...	5	0	0
Changes of Land-level in the Phlegrean Fields.....	50	0	0
Legislation regulating Women's Labour.....	15	0	0
Small Screw Gauge	45	0	0
Resistance of Road Vehicles to Traction.....	75	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	30	0	0
Anthropological Teaching ...	5	0	0
Exploration in Crete	145	0	0
Physiological Effects of Peptone.....	30	0	0
Chemistry of Bone Marrow...	5	15	11
Suprarenal Capsules in the Rabbit.....	5	0	0
Fertilisation in Phæophyceæ	15	0	0
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Corresponding Societies Committee.....	15	0	0
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1902.

Electrical Standards.....	40	0	0
Seismological Observations...	35	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	80	0	0
Relation between Absorption Spectra and Organic Substances	20	0	0
Wave-length Tables	5	0	0
Life-zones in British Carboniferous Rocks	10	0	0
Exploration of Irish Caves ...	45	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Structure of Coral Reefs of Indian Ocean.....	50	0	0

	£	s.	d.
Compound Ascidiæ of the Clyde Area	25	0	0
Terrestrial Surface Waves ...	15	0	0
Legislation regulating Women's Labour	30	0	0
Small Screw Gauge	20	0	0
Resistance of Road Vehicles to Traction.....	50	0	0
Ethnological Survey of Canada	15	0	0
Age of Stone Circles.....	30	0	0
Exploration in Crete.....	100	0	0
Anthropometric Investigation of Native Egyptian Soldiers	15	0	0
Excavations on the Roman Site at Gelligaer	5	0	0
Changes in Hæmoglobin	15	0	0
Work of Mammalian Heart under Influence of Drugs...	20	0	0
Investigation of the Cyanophyceæ	10	0	0
Reciprocal Influence of Universities and Schools	5	0	0
Conditions of Health essential to carrying on Work in Schools	2	0	0
Corresponding Societies Committee	15	0	0
	<u>£947</u>	<u>0</u>	<u>0</u>

1903.

Electrical Standards.....	35	0	0
Seismological Observations...	40	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	40	0	0
Study of Hydro-aromatic Substances	20	0	0
Erratic Blocks	10	0	0
Exploration of Irish Caves ...	40	0	0
Underground Waters of North-west Yorkshire	40	0	0
Life-zones in British Carboniferous Rocks	5	0	0
Geological Photographs	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Generum et Specierum Animalium.....	100	0	0
Tidal Bore, Sea Waves, and Beaches	15	0	0
Scottish National Antarctic Expedition	50	0	0
Legislation affecting Women's Labour	25	0	0
Researches in Crete	100	0	0
Age of Stone Circles.....	3	13	2

	£	s.	d.
Anthropometric Investigation	5	0	0
Anthropometry of the Todas and other Tribes of Southern India	50	0	0
The State of Solution of Proteids.....	20	0	0
Investigation of the Cyanophyceæ	25	0	0
Respiration of Plants	12	0	0
Conditions of Health essential for School Instruction	5	0	0
Corresponding Societies Com.	20	0	0
	<u>£845</u>	<u>13</u>	<u>2</u>

1904.

Seismological Observations...	40	0	0
Investigation of the Upper Atmosphere by means of Kites	50	0	0
Magnetic Observations at Falmouth	60	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	25	0	0
Erratic Blocks	10	0	0
Life-zones in British Carboniferous Rocks	35	0	0
Fauna and Flora of the Trias	10	0	0
Investigation of Fossiliferous Drifts	50	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	60	0	0
Development in the Frog.....	15	0	0
Researches on the Higher Crustacea	15	0	0
British and Foreign Statistics of International Trade.....	25	0	0
Resistance of Road Vehicles to Traction... ..	90	0	0
Researches in Crete	100	0	0
Researches in Glastonbury Lake Village	25	0	0
Anthropometric Investigation of Egyptian Troops	8	10	0
Excavations on Roman Sites in Britain	25	0	0
The State of Solution of Proteids.....	20	0	0
Metabolism of Individual Tissues.....	40	0	0
Botanical Photographs	4	8	11
Respiration of Plants... ..	15	0	0
Experimental Studies in Heredity	35	0	0
Corresponding Societies Committee	20	0	0
	<u>£887</u>	<u>18</u>	<u>11</u>

1905.			1906.		
	£	s. d.		£	s. d.
Electrical Standards.....	40	0 0	Electrical Standards.....	25	0 0
Seismological Observations...	40	0 0	Seismological Observations...	40	0 0
Investigation of the Upper Atmosphere by means of Kites	40	0 0	Magnetic Observations at Fal- mouth	50	0 0
Magnetic Observations at Fal- mouth	50	0 0	Magnetic Survey of South Africa	99	12 6
Wave-length Tables of Spec- tra	5	0 0	Wave-length Tables of Spectra	5	0 0
Study of Hydro-aromatic Substances	25	0 0	Study of Hydro-aromatic Sub- stances.....	25	0 0
Dynamic Isomerism	20	0 0	Aromatic Nitramines	10	0 0
Aromatic Nitramines	25	0 0	Fauna and Flora of the British Trias	7	8 11
Fauna and Flora of the British Trias	10	0 0	Crystalline Rocks of Anglesey	30	0 0
Table at the Zoological Sta- tion, Naples	100	0 0	Table at the Zoological Sta- tion, Naples	100	0 0
Index Generum et Specierum Animalium	75	0 0	Index Animalium	75	0 0
Development of the Frog ...	10	0 0	Development of the Frog.....	10	0 0
Investigations in the Indian Ocean	150	0 0	Higher Crustacea	15	0 0
Trade Statistics.....	4	4 8	Freshwater Fishes of South Africa	50	0 0
Researches in Crete	75	0 0	Rainfall and Lake and River Discharge	10	0 0
Anthropometric Investiga- tions on Egyptian Troops...	10	0 0	Excavations in Crete	100	0 0
Excavations on Roman Sites in Britain	10	0 0	Lake Village at Glastonbury	40	0 0
Anthropometric Investigations	10	0 0	Excavations on Roman Sites in Britain	30	0 0
Age of Stone Circles.....	30	0 0	Anthropometric Investigations in the British Isles	30	0 0
The State of Solution of Pro- teids.....	20	0 0	State of Solution of Proteids	20	0 0
Metabolism of Individual Tissues	30	0 0	Metabolism of Individual Tissues	20	0 0
Ductless Glands.....	40	0 0	Effect of Climate upon Health and Disease.....	20	0 0
Botanical Photographs.....	3	17 6	Research on South African Cycads	14	19 4
Physiology of Heredity.....	35	0 0	Peat Moss Deposits	25	0 0
Structure of Fossil Plants ...	50	0 0	Studies suitable for Elemen- tary Schools	5	0 0
Corresponding Societies Com- mittee.....	20	0 0	Corresponding Societies Com- mittee	25	0 0
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General Meetings.

On Wednesday, August 1, at 8.30 P.M., in the Exhibition Buildings, Sir George Darwin, K.C.B., F.R.S., resigned the office of President to Professor E. Ray Lankester, LL.D., F.R.S., who took the Chair and delivered an Address, for which see p. 3.

On Thursday, August 2, at 8 P.M., a *Conversazione* took place in the Exhibition Buildings.

On Friday, August 3, at 8.30 P.M., in the Exhibition Buildings, Dr. Tempest Anderson delivered a Discourse on 'Volcanoes.'

On Monday, August 6, at 8.30 P.M., in the Exhibition Buildings, Dr. A. D. Waller, F.R.S., delivered a Discourse on 'The Electrical Signs of Life and their Abolition by Chloroform.'

On Tuesday, August 7, at 8 P.M., a *Conversazione* took place in the Exhibition Buildings.

On Wednesday, August 8, at 2.30 P.M., the concluding General Meeting was held in the Guildhall, 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 Leicester, July 31, 1907.

PRESIDENT'S ADDRESS.



ADDRESS

BY

PROFESSOR E. RAY LANKESTER,

M.A., LL.D., D.Sc., F.R.S., F.L.S., Director of the Natural History
Departments of the British Museums,

PRESIDENT.

MY LORDS, LADIES, AND GENTLEMEN,—It is, first of all, my privilege to thank you for the distinguished honour you have done me in electing me President of this great scientific Association—an honour which is enhanced by the fact that our meeting this year is once more held in the venerable city of York, in which seventy-five years ago the British Association for the Advancement of Science held its first meeting.

It is a great pleasure to me to convey to the Lord Mayor and the dignitaries and citizens of York your hearty thanks for the invitation to meet this year in their city. It seems to have become a custom that the Association should be invited at regular intervals to assemble in the city where it took birth and to note the progress made in the objects for the furtherance of which it was founded. A quarter of a century ago we met here under the presidency of that versatile leader in public affairs—Sir John Lubbock, now Lord Avebury. That occasion was the jubilee—the fiftieth anniversary—of the Association.

Lord Avebury on that occasion gave as his presidential address a survey of the progress of science during the fifty years of the Association's existence. He had a wonderful story to tell, and told it with a fulness which was only possible to one of his wide range of knowledge and keen interest in the various branches of science. If I venture on the present occasion to say a few words as to the great features in the progress of our knowledge of Nature during the last twenty-five years, it will be readily understood that the mere volume of new knowledge to be surveyed has become so vast that a full and detailed statement such as that which Lord Avebury placed before the Association at its jubilee is no longer possible in a single address delivered from the President's chair.

Let me ask you before we go further to take for a few moments a more personal retrospect and to think of the founders of this Association, then of the great workers in science who were still alive in 1881

when last we met here and have since gone from among us, leaving their great deeds and their noble enthusiasm to inspire now and for all future time those who have vowed themselves to the advancement of science in this realm of Britain.

There must be some here who had the privilege of personal acquaintance with several of the men who founded this Association in York seventy-five years ago. I myself knew Professor John Phillips, Sir Charles Lyell, Sir Roderick Murchison, Sir David Brewster, Dr. Whewell, and Mr. Harcourt of Nuneham. All these fathers of our Association had passed away before our last meeting in York. And now, in the quarter of a century which has rolled by and brought us here again, we have lost many who took an active part in its annual meetings and were familiar figures in the scientific world of the later Victorian period. Huxley and Tyndall, Spottiswoode and Cayley, Owen and Flower, Williamson and Frankland, Falconer and Busk, Prestwich and Godwin-Austen, Rolleston and Henry Smith, Stokes and Tait, and many others are in that list, including one whose name was, and is, more often heard in our discussions than any other, though he himself never was able to join us—I mean Charles Darwin. Happily some of the scientific veterans of the nineteenth century are still living, if not with us in York. Sir Joseph Hooker, who visited the Antarctic with Ross in 1839, is still hale and hearty, and so are Alfred Russel Wallace, Lord Kelvin, Sir William Huggins, and many others who were already veteran leaders in scientific investigation when last we visited York: they are still active in thought, observation, and experiment.

In attempting to give an outline of the advancement of science in the past twenty-five years I think it is necessary to distinguish two main kinds of advancement, both of which our founders had in view. Francis Bacon gave the title 'Advancement of Learning' to that book in which he explained not merely the methods by which the increase of knowledge was possible, but advocated the promotion of knowledge to a new and influential position in the organisation of human society. His purpose, says Dean Church, was 'to make knowledge really and intelligently the interest, not of the school or the study or the laboratory only, but of society at large.' This is what our founders also intended by their use of the word 'advancement.' So that in surveying the advancement of science in the past quarter of a century we of the British Association must ask not only what are the new facts discovered, the new ideas and conceptions which have come into activity, but what progress has science made in becoming really and intelligently the interest of society at large. Is there evidence that there is an increase in the influence of science on the lives of our fellow-citizens and in the great affairs of the State? Is there an increased provision for securing the progress of scientific investigation in proportion to the urgency of its need or an increased disposition to secure the employment of really competent men trained in scientific investigation for the public service?

I. THE INCREASE OF KNOWLEDGE IN THE SEVERAL BRANCHES OF SCIENCE.

The boundaries of my own understanding and the practical consideration of what is appropriate to a brief address must limit my attempt to give to the general public who follow with friendly interest our proceedings some presentation of what has been going on in the workshops of science in this last quarter of a century. My point of view is essentially that of the naturalist, and in my endeavour to speak of some of the new things and new properties of things discovered in recent years I find it is impossible to give any systematic or detailed account of what has been done in each division of science. All that I can attempt is to mention some of the discoveries which have aroused my own interest and admiration. I feel, indeed, that it is necessary to ask your forbearance for my presumption in daring to speak of so many subjects in which I cannot claim to speak as an authority, but only as a younger brother full of fraternal pride and sympathy in the glorious achievements of the great experimentalists and discoverers of our day. The duty of attempting some indication of their work is placed upon me as your President, and it is for my effort to discharge that duty that I ask your generous consideration.

As one might expect, the progress of the knowledge of nature (for it is to that rather than to the historical, moral and mental sciences that English-speaking people refer when they use the word 'science') has consisted, in the last twenty-five years, in the amplification and fuller verification of principles and theories already accepted, and in the discovery of hitherto unknown things which either have fallen into place in the existing scheme of each science or have necessitated new views, some not very disturbing to existing general conceptions, others of a more startling and, at first sight, disconcerting character. Nevertheless I think I am justified in saying that, exciting and of entrancing interest as have been some of the discoveries of the past few years, there has been nothing to lead us to conclude that we have been on the wrong path—nothing which is really revolutionary; that is to say, nothing which cannot be accepted by an intelligible modification of previous conceptions. There is, in fact, continuity and healthy evolution in the realm of science. Whilst some onlookers have declared to the public that science is at an end, its possibilities exhausted, and but little of the hopes it raised realised, others have asserted, on the contrary, that the new discoveries—such as those relating to the X-rays and to radium—are so inconsistent with previous knowledge as to shake the foundations of science, and to justify a belief in any and every absurdity of an unrestrained fancy. These two reciprocally destructive accusations are due to a class of persons who must be described as the enemies of science. Whether their attitude is due to ignorance or traditions of self-interest, such persons exist; and it is one of the objects of this Association to combat their assertions and to demonstrate, by the discoveries announced at its meetings and the consequent orderly building

up of the great fabric of 'natural knowledge,' that Science has not come to the end of her work—has, indeed, only as yet given mankind a foretaste of what she has in store for it—that her methods and her accomplished results are sound and trustworthy, serving with perfect adaptability for the increase of true discovery and the expansion and development of those general conceptions of the processes of nature at which she aims.

New Chemical Elements.—There can be no doubt that the past quarter of a century will stand out for ever in human history as that in which new chemical elements, not of an ordinary type, but possessed of truly astounding properties, were made known with extraordinary rapidity and sureness of demonstration. Interesting as the others are, it is the discovery of radio-activity and of the element radium which so far exceeds all others in importance that we may well account it a supreme privilege that it has fallen to our lot to live in the days of this discovery. No single discovery ever made by the searchers of nature even approaches that of radio-activity in respect of the novelty of the properties of matter suddenly revealed by it. A new conception of the structure of matter is necessitated and demonstrated by it, and yet, so far from being destructive and disconcerting, the new conception fits in with, grows out of, and justifies the older schemes which our previous knowledge has formulated.

Before saying more of radio-activity, which is apt to eclipse in interest every other topic of discourse, I must recall to you the discovery of the five inert gaseous elements by Rayleigh and Ramsay, which belongs to the period on which we are looking back. It was found that nitrogen obtained from the atmosphere invariably differed in weight from nitrogen obtained from one of its chemical combinations; and thus the conclusion was arrived at by Rayleigh that a distinct gas is present in the atmosphere, to the extent of 1 per cent., which had hitherto passed for nitrogen. This gas was separated, and to it the name argon (the lazy one) was given, on account of its incapacity to combine with any other element. Subsequently this argon was found by Ramsay to be itself impure, and from it he obtained three other gaseous elements equally inert: namely neon, krypton, and xenon. These were all distinguished from one another by the spectrum, the sign-manual of an element given by the light emitted in each case by the gas when in an incandescent condition. A fifth inert gaseous element was discovered by Ramsay as a constituent of certain minerals which was proved by its spectrum to be identical with an element discovered twenty-five years ago by Sir Norman Lockyer in the atmosphere of the sun, where it exists in enormous quantities. Lockyer had given the name (helium) to this new solar element, and Ramsay thus found it locked up in certain rare minerals in the crust of the earth.

But by helium we are led back to radium, for it has been found only two years ago by Ramsay and Soddy that helium is actually formed by a gaseous emanation from radium. Astounding as the statement seems, yet that is one of the many unprecedented facts which recent study has brought to light. The alchemist's dream is, if not realised, at any rate

justified. One element is actually under our eyes converted into another ; the element radium decays into a gas which changes into another element, namely helium.

Radium, this wonder of wonders, was discovered owing to the study of the remarkable phosphorescence, as it is called—the glowing without heat—of glass vacuum-tubes through which electric currents are made to pass. Crookes, Lenard, and Röntgen each played an important part in this study, showing that peculiar rays or linear streams of at least three distinct kinds are set up in such tubes—rays which are themselves invisible, but have the property of making glass or other bodies which they strike glow with phosphorescent light. The celebrated Röntgen rays make ordinary glass give out a bright green light ; but they pass through it, and cause phosphorescence outside in various substances, such as barium platino-cyanide, calcium tungstate, and many other such salts ; they also act on a photographic plate and discharge an electrified body such as an electroscope. But the most remarkable feature about them is their power of penetrating substances opaque to ordinary light. They will pass through thin metal plates or black paper or wood, but are stopped by more or less dense material. Hence it has been possible to obtain 'shadow pictures' or skiagraphs by allowing the invisible Röntgen rays to pass through a limb or even a whole animal, the denser bone stopping the rays, whilst the skin, flesh, and blood let them through. They are allowed to fall (still invisible) on to a photographic plate, when a picture like an ordinary permanent photograph is obtained by their chemical action, or they may be made to exert their phosphorescence-producing power on a glass plate covered with a thin coating of a phosphorescent salt such as barium platino-cyanide, when a temporary picture in light and shade is seen.

The rays discovered by Röntgen were known as the X-rays, because their exact nature was unknown. Other rays studied in the electrified vacuum-tubes are known as cathode rays or radiant corpuscles, and others, again, as the Lenard rays.

It occurred to M. Henri Becquerel, as he himself tells us, to inquire whether other phosphorescent bodies besides the glowing vacuum-tubes of the electrician's laboratory can emit penetrating rays like the X-rays. I say 'other phosphorescent bodies,' for this power of glowing without heat—of giving out, so to speak, cold light—is known to be possessed by many mineral substances. It has become familiar to the public in the form of 'phosphorescent paint,' which contains sulphide of calcium, a substance which shines in the dark after exposure to sunlight—that is to say, is phosphorescent. Other sulphides and the minerals fluor-spar, apatite, some gems, and, in fact, a whole list of substances have, under different conditions of treatment, this power of phosphorescence or shining in the dark without combustion or chemical change. All, however, require some special treatment, such as exposure to sunlight or heat or pressure, to elicit the phosphorescence, which is of short duration only.

Many of the compounds of a somewhat uncommon metallic element, called uranium, used for giving a fine green colour to glass, are phosphorescent substances, and it was, fortunately, one of them which Henri Becquerel chose for experiment. Henri Becquerel is professor in the Jardin des Plantes of Paris ; his laboratory is a delightful old-fashioned building, which had for me a special interest and sanctity when, a few years ago, I visited him there, for, a hundred years before, it was the dwelling-house of the great Cuvier. Here Henri Becquerel's father and grandfather—men renowned throughout the world for their discoveries in mineralogy, electricity, and light—had worked, and here he had himself gone almost daily from his earliest childhood. Many an experiment bringing new knowledge on the relations of light and electricity had Henri Becquerel carried out in that quiet old-world place before the day on which, about twelve years ago, he made the experimental inquiry, Does uranium give off penetrating rays like Röntgen's rays ? He wrapped a photographic plate in black paper, and on it placed and left lying there for twenty-four hours some uranium salt. He had placed a cross, cut out in thin metallic copper, under the uranium powder, so as to give some shape to the photographic print should one be produced. It *was* produced. Penetrating rays were given off by the uranium : the black paper was penetrated, and the form of the copper cross was printed on a dark ground. The copper was also penetrated to some extent by the rays from the uranium, so that its image was not left actually white. Only one step more remained before Becquerel made his great discovery. It was known, as I stated just now, that sulphide of calcium and similar substances *become* phosphorescent when exposed to sunlight, and lose this phosphorescence after a few hours. Becquerel thought at first that perhaps the uranium acquired its power similarly by exposure to light ; but very soon, by experimenting with uranium long kept in the dark, he found that the emission of penetrating rays, giving photographic effects, was produced spontaneously. The emission of rays by this particular fragment of uranium has shown no sign of diminution since this discovery. The emission of penetrating rays by uranium was soon found to be independent of its phosphorescence. Phosphorescent bodies, as such, do not emit penetrating rays. Uranium compounds, whether phosphorescent or not, emit, and continue to emit, these penetrating rays, capable of passing through black paper and metallic copper. They do not derive this property from the action of light or any other treatment. The emission of these rays discovered by Becquerel is a new property of matter. It is called 'radio-activity,' and the rays are called Becquerel rays.

From this discovery by Becquerel to the detection and separation of the new element radium is an easy step in thought, though one of enormous labour and difficulty in practice. Professor Pierre Curie (whose name I cannot mention without expressing the grief with which we all heard in last April of the sad accident by which his life was taken) and his wife, Madame Sklodowski Curie, incited by Becquerel's discovery

examined the ore called pitch-blende which is worked in mines in Bohemia and is found also in Cornwall. It is the ore from which all commercial uranium is extracted. The Curies found that pitch-blende has a radio-activity four times more powerful than that of metallic uranium itself. They at once conceived the idea that the radio-activity of the uranium salts examined by Becquerel is due not to the uranium itself, but to another element present with it in variable quantities. This proved to be in part true. The refuse of the first processes by which in the manufacturer's works the uranium is extracted from its ore, pitch-blende, was found to contain four times more of the radio-active matter than does the pure uranium. By a long series of fusions, solutions, and crystallisations the Curies succeeded in 'hunting down,' as it were, the radio-active element. The first step gave them a powder mixed with barium chloride, and having 2,000 times the activity of the uranium in which Becquerel first proved the existence of the new property—radio-activity. Then step by step they purified it to a condition 10,000 times, then to 100,000 times, and finally to the condition of a crystalline salt having 1,800,000 times the activity of Becquerel's sample of uranium. The purification could go no further, but the extraordinary minuteness of the quantity of the pure radio-active substance obtained and the amount of labour and time expended in preparing it may be judged of from the fact that of one ton of the pitch-blende ore submitted to the process of purification only the hundredth of a gram—the one-seventh of a grain—remained.

The amount of radium in pitch-blende is one ten-millionth per cent. ; rarer than gold in sea-water. The marvel of this story and of all that follows consists largely in the skill and accuracy with which our chemists and physicists have learnt to deal with such infinitesimal quantities, and the gigantic theoretical results which are securely posed on this pin-point of substantial matter.

The Curies at once determined that the minute quantity of colourless crystals they had obtained was the chloride of a new metallic element with the atomic weight 225, to which they gave the name radium. The proof that radium is an element is given by its 'sign-manual'—the spectrum which it shows to the observer when in the incandescent state. It consists of six bright lines and three fainter lines in the visible part of the spectrum, and of three very intense lines in the ultraviolet (invisible) part. A very minute quantity is enough for this observation ; the lines given by radium are caused by no other known element in heaven or earth. They prove its title to be entered on the roll-call of elements.

The atomic weight was determined in the usual way by precipitating the chlorine in a solution of radium chloride by means of silver. None of the precious element was lost in the process, but the Curies never had enough of it to venture on any attempt to prepare pure metallic radium. This is a piece of extravagance no one has yet dared to undertake. Altogether the Curies did not have more than some four or five grains of

chloride of radium to experiment with, and the total amount prepared and now in the hands of scientific men in various parts of the world probably does not amount to more than sixty grains at most. When Professor Curie lectured on radium four years ago at the Royal Institution in London he made use of a small tube an inch long and of one-eighth bore, containing nearly the whole of his precious store, wrenched by such determined labour and consummate skill from tons of black shapeless pitch-blende. On his return to Paris he was one day demonstrating in his lecture room with this precious tube the properties of radium when it slipped from his hands, broke, and scattered far and wide the most precious and magical powder ever dreamed of by alchemist or artist of romance. Every scrap of dust was immediately and carefully collected, dissolved, and re-crystallized, and the disaster averted with a loss of but a minute fraction of the invaluable product.

Thus, then, we have arrived at the discovery of radium—the new element endowed in an intense form with the new property ‘radio-activity’ discovered by Becquerel. The wonder of this powder, incessantly and without loss, under any and all conditions pouring forth by virtue of its own intrinsic property powerful rays capable of penetrating opaque bodies and of exciting phosphorescence and acting on photographic plates, can perhaps be realised when we reflect that it is as marvellous as though we should dig up a stone which without external influence or change, continually poured forth light or heat, manufacturing both in itself, and not only continuing to do so without appreciable loss or change, but necessarily having always done so for countless ages whilst sunk beyond the ken of man in the bowels of the earth.

Wonderful as the story is, so far it is really simple and commonplace compared with what yet remains to be told. I will only barely and abruptly state the fact that radio-activity has been discovered in other elements, some very rare, such as actinium and polonium; others more abundant and already known, such as thorium and uranium, though their radio-activity was not known until Becquerel’s pioneer-discovery. It is a little strange and no doubt significant that, after all, pure uranium is found to have a radio-activity of its own and not to have been altogether usurping the rights of its infinitesimal associate.

The wonders connected with radium really begin when the experimental examination of the properties of a few grains is made. What I am saying here is not a systematic, technical account of radium; so I shall venture to relate some of the story as it impresses me.

Leaving aside for a moment what has been done in regard to the more precise examination of the rays emitted by radium, the following astonishing facts have been found out in regard to it: (1) If a glass tube containing radium is much handled or kept in the waistcoat pocket, it produces a destruction of the skin and flesh over a small area—in fact, a sore place. (2) The smallest trace of radium brought into a room where a charged electroscope is present, causes the discharge of the electroscope.

So powerful is this electrical action of radium that a very sensitive electrometer can detect the presence of a quantity of radium five hundred thousand times more minute than that which can be detected by the spectroscope (that is to say, by the spectroscopic examination of a flame in which minute traces of radium are present). (3) Radium actually realises one of the properties of the hypothetical stone to which I compared it giving out light and heat. For it does give out heat which it makes itself incessantly and without appreciable loss of substance or energy ('appreciable' is here an important qualifying term). It is also faintly self-luminous. Fairly sensitive thermometers show that a few granules of radium salt have always a higher temperature than that of surrounding bodies. Radium has been proved to give out enough heat to melt rather more than its own weight of ice every hour; enough heat in one hour to raise its own weight of water from the freezing-point to the boiling-point. After a year and six weeks a gram of radium has emitted enough heat to raise the temperature of a thousand kilograms of water one degree. And this is always going on. Even a small quantity of radium diffused through the earth will suffice to keep up its temperature against all loss by radiation! If the sun consists of a fraction of one per cent. of radium, this will account for and make good the heat that is annually lost by it.

This is a tremendous fact, upsetting all the calculations of physicists as to the duration in past and future of the sun's heat and the temperature of the earth's surface. The geologists and the biologists have long contended that some thousand million years must have passed during which the earth's surface has presented approximately the same conditions of temperature as at present, in order to allow time for the evolution of living things and the formation of the aqueous deposits of the earth's crust. The physicists, notably Professor Tait and Lord Kelvin, refused to allow more than ten million years (which they subsequently increased to a hundred million)—basing this estimate on the rate of cooling of a sphere of the size and composition of the earth. They have assumed that its material is self-cooling. But, as Huxley pointed out, mathematics will not give a true result when applied to erroneous data. It has now, within these last five years, become evident that the earth's material is *not* self-cooling, but on the contrary self-heating. And away go the restrictions imposed by physicists on geological time. They now are willing to give us not merely a thousand million years, but as many more as we want.

And now I have to mention the strangest of all the proceedings of radium—a proceeding in which the other radio-active bodies, actinium and thorium, resemble it. This proceeding has been entirely Rutherford's discovery in Canada, and his name must be always associated with it. Radium (he discovered) is continually giving off, apart from and in addition to the rectilinear darting rays of Becquerel—an 'emanation'—a gaseous 'emanation.' This 'emanation' is radio-active—that is, gives off Becquerel rays—and deposits 'something' upon bodies brought

near the radium so that they become radio-active, and remain so for a time after the radium is itself removed. This emanation is always being formed by a radium salt, and may be most easily collected by dissolving the salt in water, when it comes away with a rush, as a gas. Sixty milligrams of bromide of radium yielded to Ramsay and Soddy 0.124 (or about one-eighth) of a cubic millimetre of this gaseous emanation. What is it? It cannot be destroyed or altered by heat or by chemical agents; it is a heavy gas, having a molecular density of 100, and it can be condensed to a liquid by exposing it to the great cold of liquid air. It gives a peculiar spectrum of its own, and is probably a hitherto unknown inert gas—a new element similar to argon. But this by no means completes its history, even so far as experiments have as yet gone. The radium emanation decays, changes its character altogether, and loses half its radio-activity every four days. Precisely at the same rate as it decays the specimen of radium salt from which it was removed forms a new quantity of emanation, having just the amount of radio-activity which has been lost by the old emanation. All is not known about the decay of the emanation, but one thing is absolutely certain, having first been discovered by Ramsay and Soddy and subsequently confirmed by independent experiment by Madame Curie. It is this: After being kept three or four days the emanation becomes, in part at least, converted into helium—the light gas (second only in the list of elements to hydrogen), the gas found twenty-five years ago by Lockyer in the sun, and since obtained in some quantities from rare radio-active minerals by Ramsay! The proof of the formation of helium from the radium emanation is, of course, obtained by the spectroscope, and its evidence is beyond assail. Here, then, is the partial conversion or decay of one element, radium, through an intermediate stage into another. And not only that, but if, as seems probable, the presence of helium indicates the previous presence of radium, we have the evidence of enormous quantities of radium in the sun, for we know helium is there in vast quantity. Not only that, but inasmuch as helium has been discovered in most hot springs and in various radio-active minerals in the earth, it may be legitimately argued that no inconsiderable quantity of radium is present in the earth. Indeed, it now seems probable that there is enough radium in the sun to keep up its continual output of heat, and enough in the earth to make good its loss of heat by radiation into space, for an almost indefinite period. Other experiments of a similar kind have rendered it practically certain that radium itself is formed by a somewhat similar transformation of uranium, so that our ideas as to the permanence and immutability on this globe of the chemical elements are destroyed, and must give place to new conceptions. It seems not improbable that the final product of the radium emanation after the helium is removed is or becomes the metal lead!

It must be obvious from all the foregoing that radium is very slowly, but none the less surely, destroying itself. There is a definite loss of particles which, in the course of time, must lead to the destruction of the

radium, and it would seem that the large new credit on the bank of time given to biologists in consequence of its discovery has a definite, if remote, limit. With the quantities of radium at present available for experiment, the amount of loss of particles is so small, and the rate so slow, that it cannot be weighed by the most delicate balance. Nevertheless it has been calculated that radium will transform half of itself in about fifteen hundred years, and unless it were being produced in some way all of the radium now in existence would disappear much too soon to make it an important geological factor in the maintenance of the earth's temperature. As a reply to this depreciatory statement we have the discovery by Rutherford and others that radium is continually being formed afresh, and from that particular element in connection with which it was discovered—namely, uranium. Hypotheses and experiments as to the details of this process are at this moment in full swing, and results of a momentous kind, involving the building-up of an element with high atomic weight by the interaction of elements with a lower atomic weight, are thought by some physicists to be not improbable in the immediate future.

The delicate electric test for radio-activity has been largely applied in the last few years to all sorts and conditions of matter. As a result it appears that the radium emanation is always present in our atmosphere; that the air in caves is especially rich in it, as are underground waters. Tin-foil, glass, silver, zinc, lead, copper, platinum and aluminium are, all of them, slightly radio-active. The question has been raised whether this widespread radio-activity is due to the wide dissemination of infinitesimal quantities of strong radio-active elements, or whether it is the natural intrinsic property of all matter to emit Becquerel rays. This is the immediate subject of research.

Over and above the more simply appreciable facts which I have thus narrated, there comes the necessary and difficult inquiry, What does it all mean? What *are* the Becquerel rays of radio-activity? What must we conceive to be the structure and mechanism of the atoms of radium and allied elements, which can not only pour forth ceaseless streams of intrinsic energy from their own isolated substance, but are perpetually, though in infinitesimal proportions, changing their elemental nature spontaneously, so as to give rise to other atoms which we recognise as other elements?

I cannot venture as an expositor into this field. It belongs to that wonderful group of men, the modern physicists, who with an almost weird power of visual imagination combine the great instrument of exact statement and mental manipulation called mathematics, and possess an ingenuity and delicacy in appropriate experiment which must fill all who even partially follow their triumphant handling of nature with reverence and admiration. Such men now or recently among us are Kelvin, Clerk Maxwell, Crookes, Rayleigh, and J. J. Thomson.

Becquerel showed early in his study of the rays emitted by radium that some of them could be bent out of their straight path by making them pass between the poles of a powerful electro-magnet. In this way have

finally been distinguished three classes of rays given off by radium : (1) the *alpha* rays, which are only slightly bent, and have little penetrative power ; (2) the *beta* rays, easily bent in a direction opposite to that in which the alpha rays bend, and of considerable penetrative power ; (3) the *gamma* rays, which are absolutely unbendable by the strongest magnetic force, and have an extraordinary penetrative power, producing a photographic effect through a foot thickness of solid iron.

The *alpha* rays are shown to be streams of tiny bodies positively electrified, such as are given off by gas flames and red-hot metals. The particles have about twice the mass of a hydrogen atom, and they fly off with a velocity of 20,000 miles a second ; that is, 40,000 times greater than that of a rifle bullet. The heat produced by radium is ascribed to the impact of these particles of the alpha rays.

The *beta* rays are streams of corpuscles similar to those given off by the cathode in a vacuum tube. They are charged with negative electricity and travel at the velocity of 100,000 miles a second. They are far more minute than the alpha particles. Their mass is equal to the one-thousandth of a hydrogen atom. They produce the major part of the photographic and phosphorescent effects of the radium rays.

The *gamma* rays are apparently the same, or nearly the same, thing as the X-rays of Röntgen. They are probably not particles at all, but pulses or waves in the ether set up during the ejection of the corpuscles which constitute the beta rays. They produce the same effects in a much smaller degree as do the beta rays, but are more penetrating.

The kind of conceptions to which these and like discoveries have led the modern physicist in regard to the character of that supposed unbreakable body—the chemical atom—the simple and unaffected friend of our youth—are truly astounding. But I would have you notice that they are not destructive of our previous conceptions, but rather elaborations and developments of the simpler views, introducing the notion of structure and mechanism, agitated and whirling with tremendous force, into what we formerly conceived of as homogeneous or simply built-up particles, the earlier conception being not so much a positive assertion of simplicity as a non-committal expectant formula awaiting the progress of knowledge and the revelations which are now in our hands.

As I have already said, the attempt to show in detail how the marvelous properties of radium and radio-activity in general are thus capable of a pictorial or structural representation is beyond the limits both of my powers and the time allowed me ; but the fact that such speculations furnish a scheme into which the observed phenomena can be fitted is what we may take on the authority of the physicists and chemists of our day.

Intimately connected with all the work which has been done in the past twenty-five years in the nature and possible transformations of atoms is the great series of investigations and speculations on astral chemistry and the development of the chemical elements which we owe to the unremitting labour during this period of Sir Norman Lockyer.

Wireless telegraphy.—Of great importance has been the whole progress in the theory and practical handling of electrical phenomena of late years. The discovery of the Hertzian waves and their application to wireless telegraphy is a feature of this period, though I may remind some of those who have been impressed by these discoveries that the mere fact of electrical action at a distance is that which hundreds of years ago gave to electricity its name. The power which we have gained of making an instrument oscillate in accordance with a predetermined code of signalling, although detached and a thousand miles distant, does not really lend any new support to the notion that the old-time beliefs of thought-transference and second sight are more than illusions based on incomplete observation and imperfect reasoning. For the important factors in such human intercourse—namely, a signalling-instrument and a code of signals—have not been discovered, as yet, in the structure of the human body, and have to be consciously devised and manufactured by man in the only examples of thought-transference over long distances at present discovered or laid bare to experiment and observation.

High and low temperatures.—The past quarter of a century has witnessed a great development and application of the methods of producing both very low and very high temperatures. Sir James Dewar, by improved apparatus, has produced liquid hydrogen and a fall of temperature probably reaching to the absolute zero. A number of applications of extremely low temperatures to research in various directions has been rendered possible by the facility with which they may now be produced. Similarly high temperatures have been employed in continuation of the earlier work of Deville, and others by Moissan, the distinguished French chemist.

Progress in Chemistry.—In chemistry generally the theoretical tendency guiding a great deal of work has been the completion and verification of the 'periodic law' of Mendeléeff; and, on the other hand, the search by physical agents such as light and electricity for evidence as to the arrangement of atoms in the molecules of the most diverse chemical compounds. The study of 'valency' and its outcome, stereo-chemistry, have been the special lines in which chemistry has advanced. As a matter of course hundreds, if not thousands, of new chemical bodies have been produced in the laboratory of greater or less theoretical interest. The discovery of the greatest practical and industrial importance in this connection is the production of indigo by synthetical processes, first by laboratory and then by factory methods, so as to compete successfully with the natural product. Von Baeyer and Heumann are the names associated with this remarkable achievement, which has necessarily dislocated a large industry which derived its raw material from British India.¹

¹ I had at first intended to give in this address a more detailed and technical statement of the progress of science than I have found possible when actually engaged in its preparation. The limits of time and space render any such survey

Astronomy.—A biologist may well refuse to offer any remarks on his own authority in regard to this earliest and grandest of all the sciences. I will therefore at once say that my friend the Savilian Professor of Astronomy in Oxford has turned my thoughts in the right direction in regard to this subject. There is no doubt that there has been an immense 'revival' in astronomy since 1881; it has developed in every direction. The invention of the 'dry plate,' which has made it possible to apply photography freely in all astronomical work, is the chief cause of its great expansion. Photography was applied to astronomical work before 1881, but only with difficulty and haltingly. It was the dry-plate which made long exposures possible, and thus enabled astronomers to obtain regular records of faintly luminous objects such as nebulae and star-spectra. Roughly speaking, the number of stars visible to the naked eye may be stated as eight thousand: this is raised by the use of our best telescopes to a hundred million. But the number which can be photographed is indefinite and depends on length of exposure: a thousand million can certainly be so recorded.

The serious practical proposal to 'chart the sky' by means of photography certainly dates from this side of 1881. The Paris Conference of 1887, which made an international scheme for sharing the sky among eighteen observatories (still busy with the work, and producing excellent results), originated with photographs of the comet of 1882, taken at the Cape Observatory.

Professor Pickering, of Harvard, did not join this co-operative scheme, but has gradually devised methods of charting the sky very rapidly, so that he has at Harvard records of the whole sky many times over, and when new objects are discovered he can trace their history *backwards* for more than a dozen years by reference to his plates. This is a wonderful new method, a mode of keeping record of present movements and changes which promises much for the future of astronomy. By the photographic method hundreds of new variable stars and other interesting objects have been discovered. New planets have been detected by the hundred. Up to 1881 two hundred and twenty were known. In 1881 only one was found; namely, Stephania, being No. 220, discovered on May 19. Now a score at least are discovered

on this occasion impossible, and, moreover, the patience of even the general meeting of the British Association cannot be considered as unlimited. With a view to the preparation of a more detailed review, I had asked a number of friends and colleagues to send me notes on the progress and tendency in their own particular branches of science. They responded with the greatest generosity and unselfishness. I must entirely disclaim for them any responsibility for the brief detached statements made in the address. At the same time I should wish to thank them here by name for their most kind and timely help. They are: Sir William Ramsay, Mr. Soddy, Professor H. H. Turner, Dr. Marr, Dr. Haddon, Dr. Smith Woodward, Professor Sherrington, Professor Farmer, Professor Vines, Dr. D. H. Scott, Professor Meldola, Mr. Macdougall, Professor Poulton, Mr. C. V. Boys, Major MacMahon, and Mr. Mackinder.

every year. Over five hundred are now known. One of these—Eros—(No. 433) is particularly interesting, since it is nearer to the sun than is Mars, and gives a splendid opportunity for fixing with increased accuracy the sun's distance from the earth. Two new satellites to Saturn and two to Jupiter have been discovered by photography (besides one to Jupiter in 1892 by the visual telescope of the Lick Observatory). One of the new satellites of Saturn goes round that planet the *wrong way*, thus calling for a fundamental revision of our ideas of the origin of the solar system.

The introduction of photography has made an immense difference in spectroscopic work. The spectra of the stars have been readily mapped out and classified, and now the motions in the line of sight of faint stars can be determined. This 'motion in the line of sight,' which was discernible but scarcely measurable with accuracy before, now provides one of the most refined methods in astronomy for ascertaining the dimensions and motions of the universe. It gives us velocities in miles per second instead of in an angular unit to be interpreted by a very imperfect knowledge of the star's distance. The method, initiated practically by Huggins thirteen years before, was in 1881 regarded by many astronomers as a curiosity. Visual observations were begun at Greenwich in 1875, but were found to be affected by instrumental errors. The introduction of dry plates, and their application by Vogel in 1887, was the beginning of general use of the method, and line-of-sight work is now a vast department of astronomical industry. Among other by-products of the method are the 'spectroscopic doubles,' stars which we know to be double, and of which we can determine the period of revolution, though we cannot separate them visually by the greatest telescope.

Work on the sun has been entirely revolutionised by the use of photography. The last decade has seen the invention of the spectro-heliograph—which simply means that astronomers can now study *in detail* portions of the sun of which they could previously only get a bare indication.

More of the same story could be related, but enough has been said to show how full of life and progress is this most ancient and imposing of all sciences.

A minor though very important influence in the progress of astronomy has been the provision, by the expenditure of great wealth in America, of great telescopes and equipments.

In 1877 my distinguished predecessor in the presidency of the British Association started a line of mathematical research which has been very fruitful and is of great future promise for astronomy. He was able himself last year to give some account of this research to the Association. On the present occasion I may mention that as recently as last April, at the Royal Astronomical Society, two important papers were read—one by Mr. Cowell and the other by Mr. Stratton—which have their roots in Sir George Darwin's work. The former was led to suggest that the day is lengthening ten times as rapidly as had been

supposed, and the latter showed that in all probability the planets had all turned upside down since their birth.

And yet M. Brunettière and his friends wish us to believe that science is bankrupt and has no new things in store for humanity.

Geology.—In the field of geological research the main feature in the past twenty-five years has been the increasing acceptance of the evolutionary as contrasted with the uniformitarian view of geological phenomena. The great work of Suess, 'Das Antlitz der Erde,' is undoubtedly the most important contribution to physical geology within the period. The first volume appeared in 1885, and the impetus which it has given to the science may be judged of by the epithet applied to the views for which Suess is responsible—'the New Geology.' Suess attempts to trace the orderly sequence of the principal changes in the earth's crust since it first began to form. He strongly opposes the old theory of elevation, and accounts for the movements as due to differential collapse of the crust, accompanied by folding due to tangential stress. Among special results gained by geologists in the period we survey may be cited new views as to the origin of the crystalline schists, favouring a return to something like the hypogene origin advocated by Lyell; the facts as to deep-sea deposits, now in course of formation, embodied in the 'Challenger' reports on that subject: the increasing discrimination and tracking of those minor divisions of strata called 'zones'; the assignment of the Olenellus fauna of Cambrian age to a position earlier than that of the Paradoxides fauna; the discovery of Radiolaria in palæozoic rocks by special methods of examination, and the recognition of Graptolites as indices of geological horizons in lower palæozoic beds. Glacially eroded rocks in boulder-clays of permo-carboniferous age have been recognised in many parts of the world (*e.g.*, Australia and South Africa), and thus the view put forward by W. T. Blanford as to the occurrence of the same phenomena in conglomerates of this age in India is confirmed. Eozoon is finally abandoned as owing its structure to an organism. The oldest fossiliferous beds known to us are still far from the beginning of life. They contain a highly developed and varied animal fauna—and something like the whole of the older moiety of rocks of aqueous origin have failed as yet to present us with any remains of the animals or plants which must have inhabited the seas which deposited them. The boring of a coral reef initiated by Professor Sollas at the Nottingham meeting of this Association in 1893 was successfully carried out, and a depth of 1,114½ feet reached. Information of great value to geologists was thus obtained.

Animal and Vegetable Morphography.—Were I to attempt to give an account of the new kinds of animals and plants discovered since 1881, I should have to read out a bare catalogue, for time would not allow me to explain the interest attaching to each. Explorers have been busy in all parts of the world—in Central Africa, in the Antarctic, in remote parts of China, in Patagonia and Australia, and on the floor of the ocean,

as well as in caverns, on mountain tops, and in great lakes and rivers. We have learnt much that is new as to distribution ; countless new forms have been discovered, and careful anatomical and microscopical study conducted on specimens sent home to our laboratories. I cannot refrain from calling to mind the discovery of the eggs of the Australian duck-mole and hedgehog ; the fresh-water jelly-fish of Regent's Park, the African lakes, and the Delaware River ; the marsupial mole of Central Australia ; the okapi ; the young and adult of the mud-fishes of Australia, Africa, and South America ; the fishes of the Nile and Congo ; the gill-bearing earth worms and mud-worms ; the various forms of the caterpillar-like *Peripatus* ; strange deep-sea fishes, polyps and sponges.

The main result of a good deal of such investigation is measured by our increased knowledge of the pedigree of organisms, what used to be called 'classification.' The anatomical study by the Australian professors, Hill and Wilson, of the teeth and the fœtus of the Australian group of pouched mammals—the marsupials—has entirely upset previous notions, to the effect that these were a primitive group, and has shown that their possession of only one replacing tooth is a retention of one out of many such teeth (the germs of which are present), as in placental mammals ; and further that many of these marsupials have the nourishing outgrowth of the fœtus called the placenta fairly well developed, so that they must be regarded as a degenerate side-branch of the placental mammals, and not as primitive forerunners of that dominant series.

Speculations as to the ancestral connection of the great group of vertebrates with other great groups have been varied and ingenious ; but most naturalists are now inclined to the view that it is a mistake to assume any such connection in the case of vertebrates of a more definite character than we admit in the case of starfishes, shell-fish, and insects. All these groups are ultimately connected by very simple, remote, and not by proximate ancestors, with one another and with the ancestors of vertebrates.

The origin of the limbs of vertebrates is now generally agreed to be correctly indicated in the Thatcher-Mivart-Balfour theory to the effect that they are derived from a pair of continuous lateral fins, in fish-like ancestors, similar in every way to the continuous median dorsal fin of fishes.

The discovery of the formation of true spermatozoa by simple unicellular animals of the group Protozoa is a startling thing, for it had always been supposed that these peculiar reproductive elements were only formed by multicellular organisms. They have been discovered in some of the gregarina-like animalcules, the Coccidia, and also in the blood-parasites.

Among plants one of the most important discoveries relates to these same reproductive elements, the spermatozoa, which by botanists are called antherozoids. A great difference between the whole higher series of plants, the flowering plants or phanerogams, and the cryptogams or lower plants, including ferns, mosses, and algæ, was held to be that the latter

produce vibratile spermatozoa like those of animals which swim in liquid and fertilise the motionless egg-cell of the plant. Two Japanese botanists (and the origin of this discovery from Japan, from the University of Tokio, in itself marks an era in the history of science), Hirase and Ikeno, astonished the botanical world fifteen years ago by showing that motile antherozoids or spermatozoa are produced by two gymnosperms, the ging-ko tree (or *Salisburya*) and the cycads. The pollen-tube, which is the fertilising agent in all other phanerogams, develops in these cone-bearing trees, beautiful motile spermatozoa, which swim in a cup of liquid provided for them in connection with the ovules. Thus a great distinction between phanerogams and cryptogams was broken down, and the actual nature of the pollen-tube as a potential parent of spermatozoids demonstrated.

When we come to the results of the digging out and study of extinct plants and animals, the most remarkable results of all in regard to the affinities and pedigree of organisms have been obtained. Among plants the transition between cryptogams and phanerogams has been practically bridged over by the discovery that certain fern-like plants of the Coal Measures—the Cycadofilices, supposed to be true ferns, are really seed-bearing plants and not ferns at all, but phanerogams of a primitive type, allied to the cycads and gymnosperms. They have been re-christened Pteridosperms by Scott, who, together with F. Oliver and Seward, has been the chief discoverer in this most interesting field.

By their fossil remains whole series of new genera of extinct mammals have been traced through the tertiary strata of North America and their genetic connections established; and from yet older strata of the same prolific source we have almost complete knowledge of several genera of huge extinct Dinosauria of great variety of form and habit.

The discoveries by Seeley at the Cape, and by Amalitzky in North Russia of identical genera of Triassic reptiles, which in many respects resemble the Mammalia and constitute the group Theromorpha, is also a prominent feature in the palæontology of the past twenty-five years. Nor must we forget the extraordinary Silurian fishes discovered and described in Scotland by Professor Traquair. The most important discovery of the kind of late years has been that of the Upper Eocene and Miocene Mammals of the Egyptian Fayum, excavated by the Egyptian Geological Survey and by Dr. Andrews of the Natural History Museum, who has described and figured the remains. They include a huge four-horned animal as big as a rhinoceros, but quite peculiar in its characters—the *Arisinoitherium*—and the ancestors of the elephants, a group which was abundant in Miocene and Pliocene times in Europe, and Asia, and in still later times in America, and survives at the present day in its representatives the African and Indian elephant. One of the European extinct elephants—the *Tetrabelodon*—had, we have long known, an immensely long lower jaw with large chisel-shaped terminal teeth. It had been suggested by me that the modern elephant's trunk must have been derived from the soft upper jaw and

nasal area, which rested on this elongated lower jaw, by the shortening (in the course of natural selection and modification by descent) of this long lower jaw, to the present small dimensions of the elephant's lower jaw, and the consequent down-dropping of the unshortened upper jaw and lips, which thus become the proboscis. Dr. Andrews has described from Egypt and placed in the Museum in London specimens of two new genera—one *Palæomastodon*, in which there is a long, powerful jaw, an elongated face, and an increased number of molar teeth; the second, *Meritherium*, an animal with a hippopotamus-like head, comparatively minute tusks, and a well-developed complement of incisor, canine, and molar teeth, like a typical ungulate mammal. Undoubtedly we have in these two forms the indications of the steps by which the elephants have been evolved from ordinary-looking pig-like creatures of moderate size, devoid of trunk or tusks. Other remains belonging to this great mid-African Eocene fauna indicate that not only the Elephants but the Sirenia took their origin in this area. Amongst them are also gigantic forms of Hyrax, like the little Syrian coney and many other new mammals and reptiles.

Another great area of exploration and source of new things has been the southern part of Argentina and Patagonia, where Ameghino, Moreno, and Scott of Princeton have brought to light a wonderful series of extinct ant-eaters, armadillos, huge sloths, and strange ungulates, reaching back into early Tertiary times. But most remarkable has been the discovery in this area of remains which indicate a former connection with the Australian land surface. This connection is suggested by the discovery in the Santa Cruz strata, considered to be of early Tertiary date, of remains of a huge horned tortoise which is generically identical with one found fossil in the Australian area of later date, and known as *Miolania*. In the same wonderful area we have the discovery in a cave of the fresh bones, hairy skin, and dung of animals supposed to be extinct, viz., the giant sloth, *Mylodon*, and the peculiar horse, *Onhippidium*. These remains seem to belong to survivors from the last submergence of this strangely mobile land-surface, and it is not improbable that some individuals of this 'extinct' fauna are still living in Patagonia. The region is still unexplored and those who set out to examine it have, by some strange fatality, hitherto failed to carry out the professed purpose of their expeditions.

I cannot quit this immense field of gathered fact and growing generalisation without alluding to the study of animal embryology and the germ-layer theory, which has to some extent been superseded by the study of embryonic cell-lineage, so well pursued by some American microscopists. The great generalisation of the study of the germ-layers and their formation seems to be now firmly established—namely, that the earliest multicellular animals were possessed of one structural cavity, the enteron, surrounded by a double layer of cells, the ectoderm and endoderm. These Enterocœla or Cœlentera gave rise to forms having a second great body-cavity, the cœlom, which originated not as a split

between the two layers, as was supposed twenty-five years ago by Haeckel and Gegenbaur and their pupils, but by a pouching of the enteron to form one or more cavities in which the reproductive cells should develop—pouchings which became nipped off from the cavity of their origin, and formed thus the independent cœlom. The animals so provided are the Cœlomocœla (as opposed to the Enterocœla), and comprise all animals above the polyps, jelly-fish, corals, and sea-anemones. It has been established in these twenty-five years that the cœlom is a definite structural unit of the higher groups, and that outgrowths from it to the exterior (cœlomoducts) form the genital passages, and may become renal excretory organs also. The vascular system has not, as it was formerly supposed to have, any connection of origin with the cœlom, but is independent of it, in origin and development, as also are the primitive and superficial renal tubes known as nephridia. These general statements seem to me to cover the most important advance in the general morphology of animals which we owe to embryological research in the past quarter of a century.¹

Before leaving the subject of animal morphology I must apologise for my inability to give space and time to a consideration of the growing and important science of anthropology, which ranges from the history of human institutions and language to the earliest prehistoric bones and implements. Let me therefore note here the discovery of the cranial dome of *Pithecanthropus* in a river gravel in Java—undoubtedly the most ape-like of human remains, and of great age; and, further, the Eoliths of Prestwich, in the human authorship of which I am inclined to believe, though I should be sorry to say the same of all the broken flints to which the name 'Eolith' has been applied. The systematic investigation and record of savage races have taken on a new and scientific character. Such work as Baldwin Spencer's and Haddon's in Australasia furnish examples of what is being done in this way.

Physiology of Plants and Animals.—Since I have only time to pick the most important advances in each subject for brief mention, I must signalise in regard to the physiology of plants the better understanding of the function of leaf-green or chlorophyll due to Pringsheim and to the Russian Timiriaseff, the new facts as to the activity of stomata in transpiration discovered by Horace Brown, and the fixation of free nitrogen by living organisms in the soil and by organisms (*Bacillus radicola*) parasitic in the rootlets of leguminous plants, which thus benefit by a supply of nitrogenous compounds which they can assimilate.

Great progress in the knowledge of the chemistry of the living cells or protoplasm of both plants and animals has been made by the discovery of the fact that ferments or enzymes are not only secreted externally by cells, but exist active and preformed *inside* cells. Büchner's final conquest of the secret of the yeast-cell by heroic mechanical methods—

¹ See the introduction to Part II. of a Treatise on Zoology. Edited by E. Ray Lankester (London: A. & C. Black).

the actual grinding to powder of these already very minute bodies—first established this, and now successive discoveries of intracellular ferments have led to the conclusion that it is probable that the cell respire by means of a respiratory 'oxydase,' builds up new compounds and destroys existing ones, contracts and accomplishes its own internal life by ferments. Life thus (from the chemical point of view) becomes a chain of ferment actions. Another most significant advance in animal physiology has been the sequel (as it were) of Bernard's discovery of the formation of glycogen in the liver, a substance not to be excreted, but to be taken up by the blood and lymph, and in many ways more important than the more obvious formation of bile which is thrown out of the gland into the alimentary canal. It has been discovered that many glands, such as the kidney and pancreas and the ductless glands, the suprarenals, thyroid, and others, secrete indispensable products into the blood and lymph. Hence myxœdema, exophthalmic goitre, Addison's disease, and other disorders have been traced to a deficiency or excess of internal secretions from glands formerly regarded as interesting but unimportant vestigial structures. From these glands have in consequence been extracted remarkable substances on which their peculiar activity depends. From the suprarenals a substance has been extracted which causes activity of all those structures which the sympathetic nerve system can excite to action: the thyroid yields a substance which influences the growth of the skin, hair, bones, &c.; the pituitary gland, an extract which is a specific urinary stimulant. Quite lately the mammalian ovary has been shown by Starling to yield a secretion which influences the state of nutrition of the uterus and mammæ. Had I time, I might say a great deal more on topics such as these—topics of almost infinite importance; but the fact is that the mere enumeration of the most important lines of progress in any one science would occupy us for hours.

Nerve-physiology has made immensely important advances. There is now good evidence that all excitation of one group of nerve-centres is accompanied by the *concurrent inhibition* of a whole series of groups of other centres, whose activity might interfere with that of the group excited to action. In a simple reflex flexure of the knee the motor-neurones to the flexor muscles are excited, but concurrently the motor-neurones to the extensor muscles are thrown into a state of inhibition, and so equally with all the varied excitations of the nervous system controlling the movements and activities of the entire body.

The discovery of the continuity of the protoplasm through the walls of the vegetable cell by means of connecting canals and threads is one of the most startling facts discovered in connection with plant-structure, since it was held twenty years ago that a fundamental distinction between animal and vegetable structure consisted in the boxing-up or encasement of each vegetable cell-unit in a case of cellulose, whereas animal cells were not so imprisoned, but freely communicated with one another. It perhaps is on this account the less surprising that lately something like sense-

organs have been discovered on the roots, stems, and leaves of plants, which, like the otocysts of some animals, appear to be really 'statocytes,' and to exert a varying pressure according to the relations of these parts of the plant to gravity. There is apparently something resembling a perception of the incidence of gravity in plants which reacts on irritable tissues, and is the explanation of the phenomena of geotropism. These results have grown out of the observations of Charles Darwin, followed by those of F. Darwin, Haberlandt, and Nemeç.

A few words must be said here as to the progress of our knowledge of cell-substance, and what used to be called the protoplasm question. We do not now regard protoplasm as a chemical expression, but, in accordance with von Mohl's original use of the word, as a structure which holds in its meshes many and very varied chemical bodies of great complexity. Within these twenty-five years the 'centrosome' of the cell-protoplasm has been discovered, and a great deal has been learnt as to the structure of the nucleus and its remarkable stain-taking bands, the chromosomes. We now know that these bands are of definite fixed number, varying in different species of plants and animals, and that they are halved in number in the reproductive elements—the spermatozoid and the ovum—so that on union of these two to form the fertilised ovum (the parent cell of all the tissues), the proper specific number is attained. It has been pretty clearly made out by cutting up large living cells—unicellular animals—that the body of the cell alone, without the nucleus, can do very little but move and maintain for a time its chemical status. But it is the nucleus which directs and determines all definite growth, movement, secretion, and reproduction. The simple protoplasm, deprived of its nucleus, cannot form a new nucleus—in fact, can do very little but exhibit irritability. I am inclined to agree with those who hold that there is not sufficient evidence that any organism exists at the present time which has not both protoplasm and nucleus—in fact, that the simplest form of life at present existing is a highly complicated structure—a nucleated cell. That does not imply that simpler forms of living matter have not preceded those which we know. We must assume that something more simple and homogeneous than the cell, with its differentiated cell-body or protoplasm, and its cell kernel or nucleus, has at one time existed. But the various supposed instances of the survival to the present day of such simple living things—described by Haeckel and others—have one by one yielded to improved methods of microscopic examination and proved to be differentiated into nuclear and extra-nuclear substance.

The question of 'spontaneous generation' cannot be said to have been seriously revived within these twenty-five years. Our greater knowledge of minute forms of life, and the conditions under which they can survive, as well as our improved microscopes and methods of experiment and observation, have made an end of the arguments and instances of supposed abiogenesis. The accounts which have been published of 'radiobes,' minute bodies arising in fluids of organic origin when

radium salts have been allowed to mix in minute quantities with such fluids, are wanting in precision and detail, but the microscopic particles which appear in the circumstances described seem to be of a nature identical with the minute bodies well known to microscopists and recognised as crystals modified by a colloid medium. They have been described by Rainey, Harting, and Ord, on different occasions, many years ago. They are not devoid of interest, but cannot be considered as having any new bearing on the origin of living matter.

Psychology.—I have given a special heading to this subject because its emergence as a definite line of experimental research seems to me one of the most important features in the progress of science in the past quarter of a century. Thirty-five years ago we were all delighted by Fechner's psycho-physical law, and at Leipzig I, with others of my day, studied it experimentally in the physiological laboratory of that great teacher, Carl Ludwig. The physiological methods of measurement (which are the physical ones) have been more and more widely, and with guiding intelligence and ingenuity, applied since those days to the study of the activities of the complex organs of the nervous system which are concerned with 'mind' or psychic phenomena. Whilst some enthusiasts have been eagerly collecting ghost stories and records of human illusion and fancy, the serious experimental investigation of the human mind, and its forerunner the animal mind, has been quietly but steadily proceeding in truly scientific channels. The science is still in an early phase—that of the collection of accurate observations and measurements—awaiting the development of great guiding hypotheses and theories. But much has been done, and it is a matter of gratification to Oxford men that through the liberality of the distinguished electrician, Mr Henry Wilde, F.R.S., a lectureship of Experimental Psychology has been founded in the University of Oxford, where the older studies of Mental and Moral Philosophy, Logic and Metaphysics have so strong a hold, and have so well prepared the ground for the new experimental development. The German investigators W. Wundt, G. E. Müller, C. Stumpf, Ebbinghaus, and Munsterberg have been prominent in introducing laboratory methods, and have determined such matters as the elementary laws of association and memory, and the perceptions of musical tones and their relations. The work of Goldschneider on 'the muscular sense,' of von Frey on the cutaneous sensations, are further examples of what is being done.

The difficult and extremely important line of investigation, first scientifically treated by Braid under the name 'Hypnotism,' has been greatly developed by the French school, especially by Charcot. The experimental investigation of 'suggestion,' and the pathology of dual consciousness and such exceptional conditions of the mind, has been greatly advanced by French observers.

The older work of Ferrier and Hitzig on the functions of the parts of the brain has been carried further by Goltz and Munk in Germany, and by Schäfer, Horsley, and Sherrington in England.

The most important general advance seems to be the realisation that the mind of the human adult is a social product; that it can only be understood in relation with the special environment in which it develops, and with which it is in perpetual interaction. Professor Baldwin, of Princeton, has done important work on this subject. Closely allied is the study of what is called 'the psychology of groups,' the laws of mental action of the individual as modified by his membership of some form of society. French authors have done valuable work here.

These two developments of psychology are destined to provide the indispensable psychological basis for Social Science, and for the anthropological investigation of mental phenomena.

Hereafter, the well-ascertained laws of experimental psychology will undoubtedly furnish the necessary scientific basis of the art of education, and psychology will hold the same relation to that art as physiology does to the art of medicine and hygiene.

There can be little doubt, moreover, of the valuable interaction of the study of physical psychology and the theories of the origin of structural character by natural selection. The relation of the human mind to the mind of animals, and the gradual development of both, is a subject full of rich stores of new material, yielding conclusions of the highest importance, which has not yet been satisfactorily approached.

I am glad to be able to give wider publicity here to some conclusions which I communicated to the Jubilee volume of the 'Société de Biologie' of Paris in 1899. I there discussed the significance of the great increase in the size of the cerebral hemispheres in recent, as compared with Eocene Mammals, and in Man as compared with Apes, and came to the conclusion that 'the power of building up appropriate cerebral mechanism in response to individual experience,' or what may be called 'educability,' is the quality which characterises the larger cerebrum, and is that which has led to its selection, survival, and further increase in volume. The bearing of this conception upon questions of fundamental importance in what has been called genetic psychology is sketched as follows.

'The character which we describe as "educability" can be transmitted; it is a congenital character. But the *results* of education can *not* be transmitted. In each generation they have to be acquired afresh. With increased "educability" they are more readily acquired and a larger variety of them. On the other hand, the nerve-mechanisms of instinct are transmitted, and owe their inferiority as compared with the results of education to the very fact that they are *not* acquired by the individual in relation to his particular needs, but have arisen by selection of congenital variation in a long series of preceding generations.'

'To a large extent the two series of brain-mechanisms, the "instinctive" and the "individually acquired," are in opposition to one another. Congenital brain-mechanisms may prevent the education of the brain and the development of new mechanisms specially fitted to the special conditions of life. To the educable animal the less there is of specialised

mechanism transmitted by heredity, the better. The loss of instinct is what permits and necessitates the education of the receptive brain.'

'We are thus led to the view that it is hardly possible for a theory to be further from the truth than that expressed by George H. Lewes and adopted by George Romanes, namely, that instincts are due to "lapsed" intelligence. The fact is that there is no community between the mechanisms of instinct and the mechanisms of intelligence, and that the latter are later in the history of the development of the brain than the former, and can only develop in proportion as the former become feeble and defective.'¹

Darwinism.—Under the title 'Darwinism' it is convenient to designate the various work of biologists tending to establish, develop, or modify Mr. Darwin's great theory of the origin of species. In looking back over twenty-five years it seems to me that we must say that the conclusions of Darwin as to the origin of species by the survival of selected races in the struggle for existence are more firmly established than ever. And this because there have been many attempts to gravely tamper with essential parts of the fabric as he left it, and even to substitute conceptions for those which he endeavoured to establish, at variance with his conclusions. These attempts must, I think, be considered as having failed. A great deal of valuable work has been done in consequence; for honest criticism, based on observation and experiment, leads to further investigation, and is the legitimate and natural mode of increase of scientific knowledge. Amongst the attempts to seriously modify Darwin's doctrine may be cited that to assign a great and leading importance to Lamarck's theory as to the transmission by inheritance of newly 'acquired' characters, due chiefly to American palæontologists and to the venerated defender of such views, who has now closed his long life of great work, Mr. Herbert Spencer; that to attribute leading importance to the action of physiological congruity and incongruity in selective breeding, which was put forward by another able writer and naturalist who has now passed from among us, Dr. George Romanes; further, the views of de Vries as to discontinuity in the origin of new species, supported by the valuable work of Mr. Bateson on discontinuous variation; and lastly, the attempt to assign a great and general importance to the facts ascertained many years ago by the Abbé Mendel as to the cross-breeding of varieties and the frequent production (in regard to certain characters in certain cases) of pure strains rather than of breeds combining the characters of both parents. On the other hand we have the splendid series of observations and writings of August Weismann, who has, in the opinion of the majority of those who study this subject, rendered the Lamarckian theory of the origin and transmission of new characters altogether untenable, and has, besides, furnished a most

¹ From the Jubilee volume of the Soc. de Biol. of Paris, 1899. Reprinted in *Nature*, vol. lxi., 1900, pp. 624, 625.

instructive, if not finally conclusive, theory or mechanical scheme of the phenomena of Heredity in his book 'The Germ-plasm.' Professor Karl Pearson and the late Professor Weldon—the latter so early in life and so recently lost to us—have, with the finest courage and enthusiasm in the face of an enormous and difficult task, determined to bring the facts of variation and heredity into the solid form of statistical statement, and have organised, and largely advanced in, this branch of investigation, which they have termed 'Biometrics.' Many naturalists throughout the world have made it the main object of their collecting and breeding of insects, birds, and plants, to test Darwin's generalisations and to expand the work of Wallace in the same direction. A delightful fact in this survey is that we find Mr. Alfred Russel Wallace (who fifty years ago conceived the same theory as that more fully stated by Darwin) actively working and publishing some of the most convincing and valuable works on Darwinism. He is still alive and not merely well, but pursuing his work with vigour and ability. It was chiefly through his researches on insects in South America and the Malay Islands that Mr. Wallace was led to the Darwinian theory; and there is no doubt that the study of insects, especially of butterflies, is still one of the most prolific fields in which new facts can be gathered in support of Darwin and new views on the subject tested. Prominent amongst naturalists in this line of research has been and is Edward Poulton of Oxford, who has handed on to the study of entomology throughout the world the impetus of the Darwinian theory. I must here also name a writer who, though unknown in our laboratories and museums, seems to me to have rendered very valuable service in later years to the testing of Darwin's doctrines and to the bringing of a great class of organic phenomena within the cognisance of those naturalists who are especially occupied with the problems of Variation and Heredity. I mean Dr. Archdall Reid, who has with keen logic made use of the immense accumulation of material which is in the hands of medical men, and has pointed out the urgent importance of increased use by Darwinian investigators of the facts as to the variation and heredity of that unique animal, man, unique in his abundance, his reproductive activity, and his power of assisting his investigator by his own record. There are more observations about the variation and heredity of man and the conditions attendant upon individual instances than with regard to any other animal. Medical men need only to grasp clearly the questions at present under discussion in order to be able to furnish with ease data absolutely invaluable in quantity and quality. Dr. Archdall Reid has in two original books full of insight and new suggestions, the 'Present Evolution of Man' and 'Principles of Heredity,' shown a new path for investigators to follow.

The attempt to resuscitate Lamarck's views on the inheritance of acquired¹ characters has been met not only by the demand for the

¹ I use the term 'acquired' without prejudice in the sense given to that word by Lamarck himself.

production of experimental proof that such inheritance takes place, which has never been produced, but on Weismann's part by a demonstration that the reproductive cells of organisms are developed and set aside from the rest of the tissues at so early a period that it is extremely improbable that changes brought about in those other tissues by unaccustomed incident forces can be communicated to the germ-cells so as to make their appearance in the offspring by heredity. Apart from this, I have drawn attention to the fact that Lamarck's first and second laws (as he terms them) of heredity are contradictory the one of the other, and therefore may be dismissed. In 1894 I wrote:—

‘Normal conditions of environment have for many thousands of generations moulded the individuals of a given species of organism, and determined as each individual developed and grew “responsive” quantities in its parts (characters); yet, as Lamarck tells us, and as we know, there is in every individual born a potentiality which has *not* been extinguished. Change the normal conditions of the species in the case of a young individual taken to-day from the site where for thousands of generations its ancestors have responded in a perfectly defined way to the normal and defined conditions of environment; reduce the daily or the seasonal amount of solar radiation to which the individual is exposed; or remove the aqueous vapour from the atmosphere; or alter the chemical composition of the pabulum accessible; or force the individual to previously unaccustomed muscular effort or to new pressures and strains; and (as Lamarck bids us observe), in spite of all the long-continued response to the earlier normal specific conditions, the innate congenital potentiality shows itself. The individual under the new quantities of enviroing agencies shows *new* responsive quantities in those parts of its structure concerned, new or *acquired* characters.

‘So far, so good. What Lamarck next asks us to accept, as his “second law,” seems not only to lack the support of experimental proof, but to be inconsistent with what has just preceded it. The new character which is *ex hypothesi*, as was the old character (length, breadth, weight of a part) which it has replaced—a response to environment, a particular moulding or manipulation by incident forces of the potential congenital quality of the race—is, according to Lamarck, all of a sudden raised to extraordinary powers. The new or freshly acquired character is declared by Lamarck and his adherents to be capable of transmission by generation; that is to say, it alters the potential character of the species. It is no longer a merely responsive or reactive character, determined quantitatively by quantitative conditions of the environment, but becomes fixed and incorporated in the potential of the race, so as to persist when other quantitative external conditions are substituted for those which originally determined it. In opposition to Lamarck, one must urge, in the first place, that this thing has never been shown experimentally to occur; and in the second place, that there is no ground for holding its occurrence to be probable, but, on the contrary, strong reason for holding it to be

improbable. Since the old character (length, breadth, weight) had not become fixed and congenital after many thousands of successive generations of individuals had developed it in response to environment, but gave place to a new character when new conditions operated on an individual (Lamarck's first law), why should we suppose that the new character is likely to become fixed after a much shorter time of responsive existence, or to escape the operation of the first law? Clearly there is no reason (so far as Lamarck's statement goes) for any such supposition, and the two so-called laws of Lamarck are at variance with one another.'

In its most condensed form my argument has been stated thus by Professor Poulton: Lamarck's 'first law assumes that a past history of indefinite duration is powerless to create a bias by which the present can be controlled; while the second assumes that the brief history of the present can readily raise a bias to control the future.'¹

An important light is thrown on some facts which seem at first sight to favour the Lamarckian hypothesis by the consideration that, though an 'acquired' character is not transmitted to offspring as the consequence of the action of external agencies determining the 'acquirement,' yet the tendency to react exhibited by the parent *is* transmitted, and if the tendency is exceptionally great a false suggestion of a Lamarckian inheritance can readily result. This inheritance of 'variation in tendencies to react' has a wide application, and has led me to coin the word 'educability' as mentioned in the section of this address on Psychology.

The principle of physiological selection advocated by Dr. Romanes does not seem to have caused much discussion, and has been unduly neglected by subsequent writers. It was ingenious, and was based on some interesting observations, but has failed to gain support.

The observations of de Vries—showing that in cultivated varieties of plants a new form will sometimes assert itself suddenly and attain a certain period of dominance, though not having been gradually brought into existence by a slow process of selection—have been considered by him, and by a good many other naturalists, as indicating the way in which new species arise in Nature. The suggestion is a valuable one if not very novel, but a great deal of observation will have to be made before it can be admitted as really having a wide bearing upon the origin of species. The same is true of those interesting observations which were first made by Mendel, and have been resuscitated and extended with great labour and ingenuity by recent workers, especially in this country by Bateson and his pupils. If it should prove to be true that varieties when crossed do not, in the course of eventual inter-breeding, produce intermediate forms as hybrids, but that characters are either dominant or recessive, and that breeds result having pure unmixed characters—we should, in proportion as the Mendelian law is shown to apply to all tissues and organs and to a majority of organisms, have before us a

¹ *Nature*, vol. li., 1894, p. 127.

very important and determining principle in all that relates to heredity and variation. It remains, however, to be shown how far the Mendelian phenomenon is general. And it is, of course, admitted on all sides that, even were the Mendelian phenomenon general and raised to the rank of a law of heredity, it would not be subversive of Mr. Darwin's generalisations, but probably tend to the more ready application of them to the explanation of many difficult cases of the structure and distribution of organisms.

Two general principles which Mr. Darwin fully recognised appear to me to deserve more consideration and more general application to the history of species than he had time to give to them, or than his followers have accorded to them. The first is the great principle of 'correlation of variation,' from which it follows that, whilst natural selection may be favouring some small and obscure change in an unseen group of cells—such as digestive, pigmentary or nervous cells, and that change a change of selective value—there may be, indeed often is, as we know, a correlated or accompanying change in a physiologically related part of far greater magnitude and prominence to the eye of the human onlooker. This accompanying or correlated character has no selective value, is not an adaptation—is, in fact, a necessary but useless by-product. A list of a few cases of this kind was given by Darwin, but it is most desirable that more should be established. For they enable us to understand how it is that specific characters, those seen and noted on the surface by systematists, are not in most cases adaptations of selective value. They also open a wide vista of incipient and useless developments which may suddenly, in their turn, be seized upon by ever-watchful natural selection and raised to a high pitch of growth and function.

The second, somewhat but by no means altogether neglected, principle is that a good deal of the important variation in both plants and animals is not the variation of a minute part or confined to one organ, but has really an inner physiological basis, and may be a variation of a whole organic system or of a whole tissue expressing itself at several points and in several shapes. In fact, we should perhaps more generally conceive of variation as not so much the accomplishment and presentation of one little mark or difference in weight, length, or colour, as the expression of a *tendency to vary* in a given tissue or organ in a particular way. Thus we are prepared for the rapid extension and dominance of the variation if once it is favoured by selective breeding. It seems to me that such cases as the complete disappearance of scales from the integument of some osseous fishes, or the possible retention of three or four scales out of some hundreds present in nearly allied forms, favour this mode of conceiving of variation. So also does the marked tendency to produce membranous expansions of the integument in the bats, not only between the digits and from the axilla, but from the ears and different regions of the face. Of course, the alternative hairy or smooth condition of the integuments both in plants and animals is a familiar instance in which a tendency extending over a large area is recognised as that which

constitutes the variation. In smooth or hairy varieties we do not postulate an individual development of hairs subjected one by one to selection and survival or repression.

Disease.—The study of the physiology of unhealthy, injured, or diseased organisms is called pathology. It necessarily has an immense area of observation and is of transcending interest to mankind who do not accept their diseases unresistingly and die as animals do, so purifying their race, but incessantly combat and fight disease, producing new and terrible forms of it, by their wilful interference with the earlier rule of Nature.

Our knowledge of disease has been enormously advanced in the last quarter of a century, and in an important degree our power of arresting it, by two great lines of study going on side by side and originated, not by medical men nor physiologists in the narrow technical sense, but by naturalists, a botanist, and a zoologist. Ferdinand Cohn, Professor of Botany in Breslau, by his own researches and by personal training in his laboratory, gave to Robert Koch the start on his distinguished career as a bacteriologist. It is to Metschnikoff the zoologist and embryologist that we owe the doctrine of phagocytosis and the consequent theory of immunity now so widely accepted.

We must not forget that in this same period much of the immortal work of Pasteur on hydrophobia, of Behring and Roux on diphtheria, and of Ehrlich and many others to whom the eternal gratitude of mankind is due, has been going on. It is only some fifteen years since Calmette showed that if cobra poison were introduced into the blood of a horse in less quantity than would cause death, the horse would tolerate with little disturbance after ten days a full dose, and then day after day an increasing dose, until the horse without any inconvenience received an injection of cobra poison large enough to kill thirty horses of its size. Some of the horse's blood being now withdrawn was found to contain a very active antidote to cobra poison—what is called an antitoxin. The procedure and preparation of the antitoxin is practically the same as that previously adopted by Behring in the preparation of the antitoxin of diphtheria poison. Animals treated with injections of these antitoxins are immune to the poison itself when subsequently injected with it, or, if already suffering from the poison (as, for instance, by snake-bite), are readily shown by experiment to be rapidly cured by the injection of the appropriate antitoxin. This is, as all will admit, an intensely interesting bit of biology. The explanation of the formation of the antitoxin in the blood and its mode of antagonising the poison is not easy. It seems that the antitoxin is undoubtedly formed from the corresponding toxin or poison, and that the antagonism can be best understood as a chemical reaction by which the complex molecule of the poison is upset, or effectively modified.

The remarkable development of Metschnikoff's doctrine of phagocytosis during the past quarter of a century is certainly one of the

characteristic features of the activity of biological science in that period. At first ridiculed as 'Metschnikoffism,' it has now won the support of its former adversaries.

For a long time the ideal of hygienists has been to preserve man from all contact with the germs of infection, to destroy them and destroy the animals conveying them, such as rats, mosquitoes and other flies. But it has now been borne in upon us that, useful as such attempts are, and great as is the improvement in human conditions which can thus be effected, yet we cannot hope for any really complete or satisfactory realisation of the ideal of escape from contact with infective germs. The task is beyond human powers. The conviction has now been arrived at that, whilst we must take every precaution to diminish infection, yet our ultimate safety must come from within—namely, from the activity, the trained, stimulated, and carefully guarded activity, of those wonderful colourless amœba-like corpuscles whose use was so long unrecognised, but has now been made clear by the patiently continued experiments and arguments of Metschnikoff, who has named them 'phagocytes.' The doctrine of the activity and immense importance of these corpuscles of the living body which form part of the all-pervading connective tissues and float also in the blood, is in its nature and inception opposed to what are called the 'humoral' and 'vitalistic' theories of resistance to infection. Of this kind were the beliefs that the *liquids* of the living body have an inherent and somewhat vague power of resisting infective germs, and even that the mere living quality of the tissues was in some unknown way antagonistic to foreign intrusive disease-germs.

The first eighteen years of Metschnikoff's career, after his undergraduate course, were devoted to zoological and embryological investigations. He discovered many important facts, such as the alternation of generations in the parasitic worm of the frog's lung—*Ascaris nigrovenosa*—and the history of the growth from the egg of sponges and medusæ. In these latter researches he came into contact with the wonderfully active cells, or living corpuscles, which in many low forms of life can be seen by transparency in the living animal. He saw that these corpuscles (as was indeed already known) resemble the well-known amœba, and can take into their soft substance (protoplasm) at all parts of their surface any minute particles and digest them, thus destroying them. In a transparent water-flea Metschnikoff saw these amœba-like, colourless, floating blood-corpuscles swallowing and digesting the spores of a parasitic fungus which had attacked the water-fleas and was causing their death. He came to the conclusion that this is the chief, if not the whole, value of these corpuscles in higher as well as lower animals, in all of which they are very abundant. It was known that when a wound bringing in foreign matter is inflicted on a vertebrate animal the blood-vessels become gorged in the neighbourhood and the colourless corpuscles escape through the walls of the vessels in crowds. Their business in so doing, Metschnikoff showed, is to eat up the foreign matter, and also to eat up and remove the dead,

wounded tissue. He therefore called these white or colourless corpuscles 'phagocytes,' the eater-cells, and in his beautiful book on Inflammation, published twenty years ago, proved the extreme importance of their activity. At the same time he had shown that they eat up intrusive bacteria and other germs; and his work for the last twenty years has mainly consisted in demonstrating that they are the chief, and probably the only, agents at work in either ridding the human body of an attack of disease-causing germs or in warding off even the commencement of an attack, so that the man or animal in which they are fully efficient is 'immune'—that is to say, cannot be effectively attacked by disease-germs.

Disease-germs, bacteria, or protozoa produce poisons which sometimes are too much for the phagocytes, poisoning them and so getting the upper hand. But, as Metschnikoff showed, the training of the phagocytes by weak doses of the poison of the disease-germ, or by weakened cultures of the disease-germ itself, brings about a power of resistance in the phagocytes to the germ's poison, and thus makes them capable of attacking the germs and keeping them at bay. Hence the value of inoculations.

The discussion and experiments arising from Metschnikoff's demonstrations have led to the discovery of the production by the phagocytes of certain exudations from their substance which have a most important effect in weakening the resistance of the intrusive bacteria and rendering them easy prey for the phagocyte. These are called 'sensitisers,' and have been largely studied. They may be introduced artificially into the blood and tissues so as to facilitate the work of the phagocytes, and no doubt it is a valuable remedial measure to make use of such sensitisers as a treatment. Dr. Wright considers that such sensitisers are formed in the blood and tissues independently of the phagocytes, and has called them 'opsonins,' under which name he has made most valuable application of the method of injecting them into the body so as to facilitate the work of the phagocytes in devouring the hostile bacteria of various diseases. Each kind of disease-producing microbe has its own sensitiser or opsonin; hence there has been much careful research and experiment required in order to bring the discovery to practical use. Metschnikoff himself holds and quotes experiments to show that the 'opsonins' are actually produced by the phagocytes themselves. That this should be so is in accordance with some striking zoological facts, as I pointed out nearly twenty years ago. For the lowest multicellular animals provided with a digestive sac or gut, such as the polyps, have that sac lined by digestive cells which have the same amœboid character as 'phagocytes,' and actually digest to a large extent by swallowing or taking into their individual protoplasm raw particles of food. Such particles are enclosed in a temporary cavity, or vacuole, into which the cell-protoplasm secretes digestive ferment and other chemical agents. Now there is no doubt that such digestive vacuoles may burst and so pour out into the polyp's stomach a digestive juice which will act on food particles outside the substance of the cells, and thus by the substitution of this process of outpouring of the secretion

for that of ingestion of food particles into the cells we get the usual form of digestion by juices secreted into a digestive cavity. Now this being certainly the case in regard to the history of the original phagocytes lining the polyp's gut, it does not seem at all unlikely, but on the contrary in a higher degree probable, that the phagocytes of the blood and tissues should behave in the same way and pour out sensitisers and opsonins to paralyse and prepare their bacterial food. And the experiments of Metschnikoff's pupils and followers show that this is undoubtedly the case. Whether there is any great variety of and difference between 'sensitisers' and 'opsonins' is a matter which is still the subject of active experiment. Metschnikoff's conclusion, as recently stated in regard to the whole progress of this subject, is that the phagocytes in our bodies should be stimulated in their activity in order successfully to fight the germs of infection. Alcohol, opium, and even quinine, hinder the phagocytic action; they should therefore be entirely eschewed or used only with great caution where their other and valuable properties are urgently needed. It appears that the injection of blood-serum into the tissues of animals causes an increase in the number and activity of the phagocytes, and thus an increase in their resistance towards pathogenic germs. Thus Durham (who was a pioneer in his observations on the curious phenomena of the 'agglutination' of blood corpuscles in relation to disease) was led to suggest the injection of sera during surgical operations, and experiments recently quoted by Metschnikoff seem to show that the suggestion was well founded. Both German and French surgeons have employed the method with successful results, and the demonstration that an immense number of microbes are thus taken up and destroyed by the multiplication (due to their regular increase by cell-division) of the phagocytes of the injected patient. After years of opposition bravely met in the pure scientific spirit of renewed experiment and demonstration, Metschnikoff is at last able to say that the foundation-stone of the hygiene of the tissues—the thesis that our phagocytes are our arms of defence against infective germs—has been generally accepted.

Another feature of the progress of our knowledge of disease—as a scientific problem—is the recent recognition that minute animal parasites of that low degree of unicellular structure to which the name 'Protozoa' is given, are the causes of serious and ravaging diseases, and that the minute algoid plants, the bacteria, are not alone in possession of this field of activity. It was Laveran—a French medical man—who, just about twenty-five years ago, discovered the minute animal organism in the red blood-corpuscles, which is the cause of malaria. Year by year ever since our knowledge of this terrible little parasite has increased. We now know many similar to, but not identical with it, living in the blood of birds, reptiles, and frogs.

It is the great merit of Major Ross, formerly of the Indian Army Medical Staff, to have discovered, by most patient and persevering experiment, that the malaria parasite passes a part of its life in the spot-

winged gnat or mosquito (*Anopheles*), not, as he had at first supposed, in the common gnat or mosquito (*Culex*), and that if we can get rid of spot-winged mosquitoes or avoid their attentions, or even only prevent them from sucking the blood of malarial patients, we can lessen, or even abolish, malaria.

This great discovery was followed by another as to the production of the deadly 'Nagana' horse and cattle disease in South Africa by a screw-like, minute animal parasite, the *Trypanosoma Brucei*. The Tsetse fly, which was already known in some way to produce this disease, was found by Colonel David Bruce to do so by conveying by its bite the *Trypanosoma* from wild big-game animals, to the domesticated horses and cattle of the colonists. The discovery of the parasite and its relation to the fly and the disease was as beautiful a piece of scientific investigation as biologists have ever seen. A curious and very important fact was discovered by Bruce—namely, that the native big game (zebras, antelopes, and probably buffaloes), are *tolerant* of the parasite. The *Trypanosoma* grows and multiplies in their blood, but does not kill them or even injure them. It is only the unaccustomed introduced animals from Europe which are poisoned by the chemical excreta of the *Trypanosomes* and die in consequence. Hence the wild creatures—brought into a condition of tolerance by natural selection and the dying out of those susceptible to the poison—form a sort of 'reservoir' of deadly *Trypanosomes* for the Tsetse flies to carry into the blood of new-comers. The same phenomenon of 'reservoir-hosts' (as I have elsewhere called them) has since been observed in the case of malaria; the children of the native blacks in Africa and in other malarious regions are *tolerant* of the malarial parasite, as many as 80 per cent. of children under ten being found to be infected, and yet not suffering from the poison. This is not the same thing as the immunity which consists in *repulsion* or *destruction* of the parasite.

The *Trypanosomes* have acquired a terrible notoriety within the last four years, since another species, also carried by a Tsetse fly of another species, has been discovered by Castellani in cases of sleeping sickness in Uganda, and demonstrated by Colonel Bruce to be the cause of that awful disease. Over 200,000 natives of Uganda have died from it within the last five years. It is incurable, and, sad to relate, not only a certain number of European employés have succumbed to it in tropical Africa, but a brave young officer of the Army Medical Corps, Lieutenant Tulloch, has died from the disease acquired by him in the course of an investigation of this disease and its possible cure, which he was carrying out, in association with other men of science, on the Victoria Nyanza Lake in Central Africa. Lieutenant Tulloch was sent out to this investigation by the Royal Society of London, and I will venture to ask you to join that body in sympathy for his friends, and admiration for him and the other courageous men who risk their lives in the endeavour to arrest disease.

Trypanosomes are now being recognised in the most diverse regions of the world as the cause of disease—new horse diseases in South America,

in North Africa, in the Philippines and East India are all traced to peculiar species of Trypanosome. Other allied forms are responsible for Delhi-sore, and certain peculiar Indian fevers of man. A peculiar and ultra-minute parasite of the blood cells causes Texas fever, and various African fevers deadly to cattle. In all these cases, as also in that of plague, the knowledge of the carrier of the disease, often a tick or acarid—in that of plague the flea of the rat—is extremely important, as well as the knowledge of reservoir-hosts when such exist.

The zoologist thus comes into closer touch than ever with the profession of medicine, and the time has arrived when the professional students of disease fully admit that they must bring to their great and hopeful task of abolishing the diseases of man the fullest aid from every branch of biological science. I need not say how great is the contentment of those who have long worked at apparently useless branches of science, in the belief that all knowledge is good, to find that the science they have cultivated has become suddenly and urgently of the highest practical value.

I have not time to do more than mention here the effort that is being made by combined international research and co-operation to push further in our knowledge of phthisis and of cancer, with a view to their destruction. It is only since our last meeting at York that the parasite of Phthisis or Tubercle has been made known; we may hope that it will not be long before we have similar knowledge as to Cancer. Only eighteen months have elapsed since Fritz Schaudinn discovered the long-sought parasitic germ of Syphilis, the *Spirocheta pallida*. As I write these words the sad news of Schaudinn's death at the age of thirty-five comes to me from his family at Hamburg—an irreparable loss.

Let me finally state, in relation to this study of disease, what is the simple fact—namely, that if the people of Britain wish to make an end of infective and other diseases they must take every possible means to discover capable investigators, and employ them for this purpose. To do this, far more money is required than is at present spent in that direction. It is necessary, if we are to do our utmost, to spend a thousand pounds of public money on this task where we now spend one pound. It would be reasonable and wise to expend ten million pounds a year of our revenues on the investigation and attempt to destroy disease. Actually, what is so spent is a mere nothing, a few thousands a year. Meanwhile our people are dying by thousands of preventable disease.

II. THE ADVANCEMENT OF SCIENCE AS MEASURED BY THE SUPPORT GIVEN TO IT BY PUBLIC FUNDS, AND THE RESPECT ACCORDED TO SCIENTIFIC WORK BY THE BRITISH GOVERNMENT AND THE COMMUNITY AT LARGE.

Whilst I have been able, though in a very fragmentary and incomplete way, to indicate the satisfactory and, indeed, the wonderful progress of science since this Association last met in York, so far as the making of

new knowledge is concerned, I am sorry to say that there is by no means a corresponding 'advancement' of Science in that signification of the word which implies the increase of the influence of science in the life of the community, the increase of the support given to it, and of the desire to aid in its progress, to discover and then to encourage and reward those who are specially fitted to increase scientific knowledge, and to bring it to bear so as to promote the welfare of the community. I am speaking on a privileged occasion to a body of men who are met together for the Advancement of Science, and I claim the right to say to them, without offence to the representatives of institutions which I criticise, what is in my mind.

It is, unfortunately, true that the successive political administrators of the affairs of this country, as well as the permanent officials, are altogether unaware to-day, as they were twenty-five years ago, of the vital importance of that knowledge which we call science, and of the urgent need for making use of it in a variety of public affairs. Whole departments of Government in which scientific knowledge is the one thing needful are carried on by ministers, permanent secretaries, assistant secretaries, and clerks who are wholly ignorant of science, and naturally enough dislike it since it cannot be used by them, and is in many instances the condemnation of their official employment. Such officials are, of course, not to be blamed, but rather the general indifference of the public to the unreasonable way in which its interests are neglected.

A difficult feature in treating of this subject is that when one mentions the fact that ministers of State and the officials of the public service are not acquainted with science, and do not even profess to understand its results or their importance, one's statement of this very obvious and notorious fact is apt to be regarded as a personal offence. It is difficult to see wherein the offence lies, for no one seeks to blame these officials for a condition of things which is traditional and frankly admitted.

This is really a very serious matter for the British Association for the Advancement of Science to consider and deal with. We represent a line of activity, a group of professions which are in our opinion of vital importance to the well-being of the nation. We know that those interests which we value so highly are not merely ignored and neglected, but are actually treated as of no account or as non-existent by the old-established class of politicians and administrators. It is not too much to say that there is a natural fear and dislike of scientific knowledge on the part of a large proportion of the persons who are devoid of it, and who would cease to hold, or never have held, the positions of authority or emolument which they now occupy, were scientific knowledge of the matters with which they undertake to deal required of them. This is a thorny subject, and one in which, however much one may endeavour to speak in general terms, it is difficult to avoid causing personal annoyance. Yet it seems to me one which, believing as I do that it is of most urgent importance, it is my duty as your President to press upon the attention of the

members of the British Association. Probably an inquiry into and discussion of the neglect of science and the questionable treatment of scientific men by the administrative departments of Government, would be more appropriate to a committee appointed by the Council of the Association for this purpose than to the Presidential Address.

At the same time, I think the present occasion is one on which attention should be drawn in general terms to the fact that science is not gaining 'advancement' in public and official consideration and support. The reason is, I think, to be found in the defective education, both at school and university, of our governing class, as well as in a racial dislike among all classes to the establishment and support by public funds of posts which the average man may not expect to succeed by popular clamour or class privilege in gaining for himself—posts which must be held by men of special training and mental gifts. Whatever the reason for the neglect, the only remedy which we can possibly apply is that of improved education for the upper classes, and the continued effort to spread a knowledge of the results of science and a love for it amongst all members of the community. If members of the British Association took this matter seriously to heart they might do a great deal by insisting that their sons, and their daughters too, should have reasonable instruction in science both at school and college. They could, by their own initiative and example, do a good deal to put an end to the trifling with classical literature and the absorption in athletics which is considered by too many schoolmasters as that which the British parent desires as the education of his children.

Within the past year a letter has been published by a well-known nobleman, who is one of the Trustees of the British Museum, holding up to public condemnation the method in which the system laid down by the officials of the Treasury and sanctioned by successive Governments, as to the remuneration of scientific men, was applied in an individual case. I desire to place on record here the Earl of Crawford's letter to the 'Times' of October 31, 1905, for the careful consideration of the members of the British Association and their friends. When such things are done, science cannot be said to have advanced much in public consideration or Governmental support.

To the Editor of the 'Times.'

Sir,—The death, noted by you to-day, of my dear friend and colleague Dr. Copeland, His Majesty's Astronomer for Scotland, creates a vacancy in the scientific staff of Great Britain.

Will you permit me, Sir, to offer a word of warning to any who may be asked to succeed him?

Students or masters of astronomy are not, in the selfish sense, business men, nor are they as a general rule overburdened with this world's goods. It behoves them henceforth to take more care as to their future in case of illness or physical infirmity, and not to trust to the gratitude or generous impulse of the Treasury Department.

In old days it was the custom when a man distinguished in science was brought into a high position in the Civil Service that he was credited with a certain number

of years' service ranking for pension. This practice has been done away with; and a bargain system substituted. A short while ago the growing agonies of heart disease caused Dr. Copeland to feel that he was less able to carry on the duties of his post, and he determined to resign; but he learnt that under the scale, and in the absence of any special bargain, the pension he would receive would not suffice for the necessities of life. The only increase his friends could get from the Treasury was an offer to allow him about half-a-crown a week extra by way of a house.

Indignant and ashamed of my Government, I persuaded Dr. Copeland to withdraw his resignation and to retain the official position which he has honoured till his death.

I trust, Sir, that this memorandum of mine may cause eminent men of science who are asked to enter the service of the State when already of middle age to take heed for their future welfare.

I am, Sir, your obedient servant,

CRAWFORD.

2 Cavendish Square, October 28.

It is more agreeable to me not to dwell further on the comparative failure of science to gain increased influence and support in this country, but to mention to you some instances on the other side of the account. As long ago as 1842 the British Association took over and developed an observatory in the Deer Park at Kew, which was placed at the disposal of the Association by Her Majesty the Queen. Until 1871 the Association spent annually a large part of its income—as much in later years as 600*l.* a year in carrying on the work of the Kew Observatory, consisting of magnetic, meteorological, and physical observations. In 1871 the Association handed over the Observatory to the Royal Society, which had received an endowment of 10,000*l.* from Mr. Gassiot for its maintenance, and had further devoted to that purpose considerable sums from its own Donation Fund and Government Grant. Further aid for it was also received from private sources. From this Observatory at last has sprung, in the beginning of the present century, the National Physical Laboratory in Bushey Park, a fine and efficient scientific institution, built and supported by grants from the State, and managed by a committee of really devoted men of science who are largely representatives of the Royal Society. In addition to the value of the site and buildings occupied by the National Physical Laboratory, the Government has contributed altogether 34,000*l.* to the capital expenditure on new buildings, fittings, and apparatus, and has further assigned a grant of 6,000*l.* a year to the working of the laboratory. This institution all men of science are truly glad to have gained from the State, and they will remember with gratitude the statesmen—the late Marquis of Salisbury, the Right Hon. Arthur J. Balfour, Mr. Haldane, and others—as well as their own leaders—Lord Rayleigh, Sir William Huggins, and the active body of physicists in the Royal Society who have carried this enterprise to completion. The British Association has every reason to be proud of its share in early days in nursing the germ at Kew which has at length expanded into this splendid national institution.

I may mention also another institution which, during the past quarter

of a century, has come into existence and received, originally through the influence of the late Lord Playfair (one of the few men of science who has ever occupied the position of Minister of the Crown), and later by the influence of the Right Hon. Joseph Chamberlain, a subsidy of 1,000*l.* a year from the Government and a contribution of 5,000*l.* towards its initial expenses. This is the Marine Biological Association, which has a laboratory at Plymouth, and has lately expended a special annual grant, at the spontaneous invitation of His Majesty's Treasury, in conducting an investigation of the North Sea in accordance with an international scheme devised by a central committee of scientific experts. This scheme has for its purpose the gaining such knowledge of the North Sea and its inhabitants as shall be useful in dealing practically and by legislation with the great fisheries of that area. You will, perhaps, not be surprised to hear that there are persons in high positions who, though admittedly unacquainted with the scientific questions at issue or the proper manner of solving them, are discontented with the action of the Government in entrusting the expenditure of public money to a body of scientific men who give their services, without reward or thanks, to carrying out the purposes of the international inquiry. Strange criticisms are offered by these malcontents in regard to the work done in the international exploration of the North Sea, and a desire is expressed to secure the money for expenditure by a less scientific agency. I do not hesitate to say here that the results obtained by the Marine Biological Association are of great value and interest, and, if properly continued and put to practical application, are likely to benefit very greatly the fishery industry; on the other hand, if the work is cut short or entrusted to incompetent hands it will no doubt be the case that what has already been done will lose its value—that is to say, will have been wasted. There is imminent danger of this perversion of the funds assigned to this scientific investigation taking place. There is no guarantee for the continuance of any funds or offices assigned to science in one generation by the officials of the next. The Mastership of the Mint held by Isaac Newton, and finally by Thomas Graham, has been abolished and its salary appropriated by non-scientific officials. Only a few years ago it was with great difficulty that the Government of the day was prevented from assigning the Directorship of Kew Gardens to a young man of influence devoid of all knowledge of botany!

One of the most solid tests of the esteem and value attached to scientific progress by the community is the dedication of large sums of money to scientific purposes by its wealthier members. We know that in the United States such gifts are not infrequent; they are rare in this country. It is, therefore, with especial pleasure that I call your attention to a great gift to science in this country made only a few years ago. Lord Iveagh has endowed the Lister Institute, for researches in connection with the prevention of disease, with no less a sum than a quarter of a million pounds sterling. This is the largest gift ever made to science in this

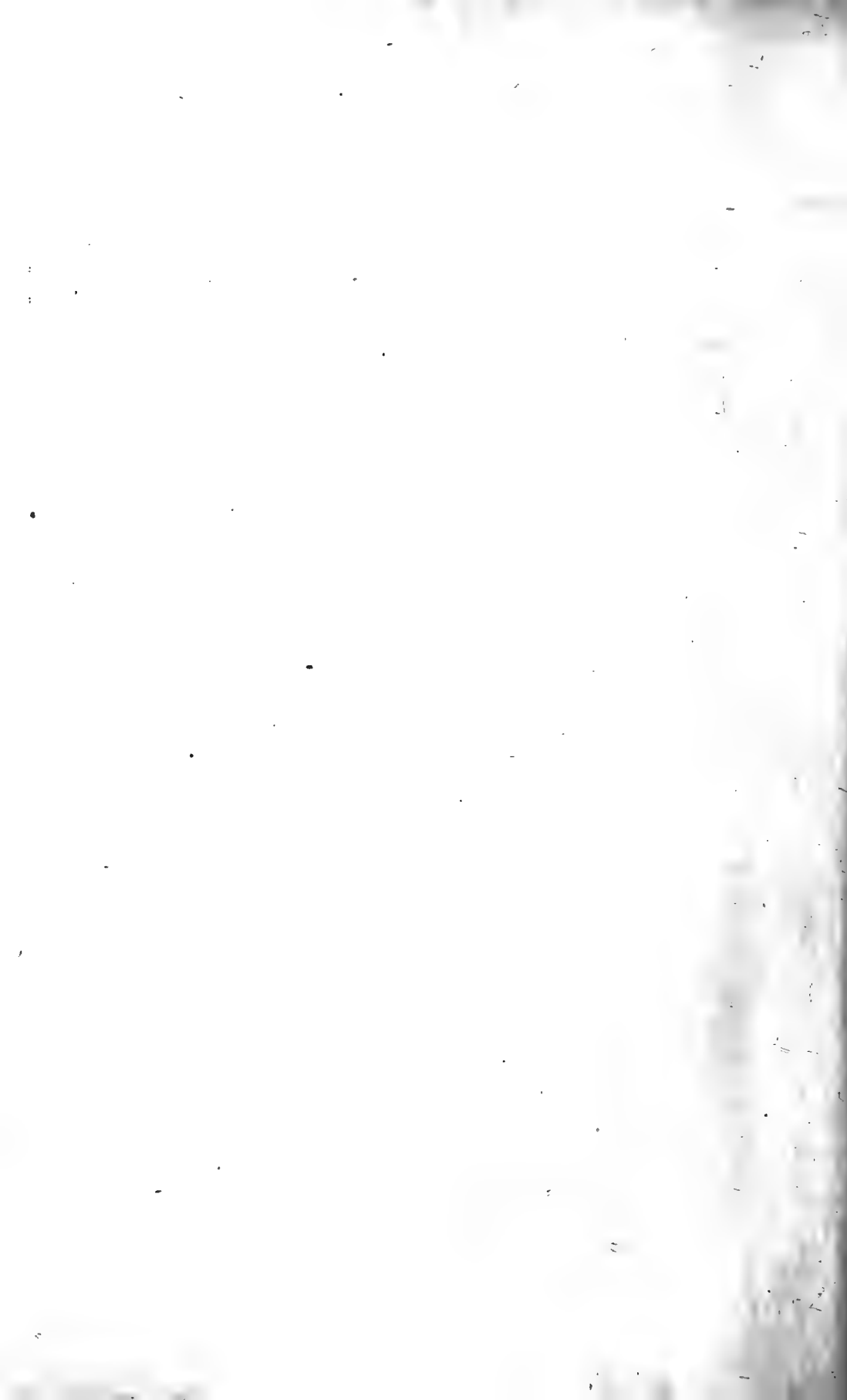
country, and will be productive of great benefit to humanity. The Lister Institute took its origin in the surplus of a fund raised by Sir James Whitehead when Lord Mayor, some sixteen years ago, for the purpose of making a gift to the Pasteur Institute in Paris, where many English patients had been treated without charge, after being bitten by rabid dogs. Three thousand pounds was sent to M. Pasteur, and the surplus of a few hundred pounds was made the starting-point of a fund which grew, by one generous gift and another, until the Lister Institute on the Thames Embankment at Chelsea was set up on a site presented by that good and high-minded man, the late Duke of Westminster.

Many other noble gifts to scientific research have been made in this country during the period on which we are looking back. Let us be thankful for them, and admire the wise munificence of the donors. But none the less we must refuse to rely entirely on such liberality for the development of the army of science, which has to do battle for mankind against the obvious disabilities and sufferings which afflict us and can be removed by knowledge. The organisation and finance of this army should be the care of the State.

It is a fact which many of us who have observed it regret very keenly, that there is to-day a less widespread interest than formerly in natural history and general science, outside the strictly professional arena of the school and university. The field naturalists among the squires and the country parsons seem nowadays not to be so numerous and active in their delightful pursuits as formerly, and the Mechanics' Institutes and Lecture Societies of the days of Lord Brougham have given place, to a very large extent, to musical performances, bioscopes, and other entertainments, more diverting, but not really more capable of giving pleasure than those in which science was popularised. No doubt the organisation and professional character of scientific work are to a large extent the cause of this falling-off in its attraction for amateurs. But perhaps that decadence is also due in some measure to the increased general demand for a kind of manufactured gaiety, readily sent out in these days of easy transport from the great centres of fashionable amusement to the provinces and rural districts.

In conclusion, I would say a word in reference to the associations of our place of meeting, the birthplace of our Association. It seems to me not inappropriate that an Association for the Advancement of Science should have taken its origin under the walls of York Minster, and that the clergy of the great cathedral should have stood by its cradle. It is not true that there is an essential antagonism between the scientific spirit and what is called the religious sentiment. 'Religion,' said Bishop Creighton, 'means the knowledge of our destiny and of the means of fulfilling it.' We can say no more and no less of Science. Men of Science seek, in all reverence, to discover the Almighty, the Everlasting. They claim sympathy and friendship with those who, like themselves, have turned away from the more material struggles of human life, and have set their hearts and minds on the knowledge of the Eternal.

REPORTS
ON THE
STATE OF SCIENCE.



REPORTS

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Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (Chairman), Mr. F. W. RUDLER (Secretary), Rev. J. O. BEVAN, Dr. HORACE T. BROWN, Dr. VAUGHAN CORNISH, Dr. J. G. GARSON, Principal E. H. GRIFFITHS, Mr. T. V. HOLMES, Mr. J. HOPKINSON, Professor R. MELDOLA, Dr. H. R. MILL, Mr. C. H. READ, Rev. T. R. R. STEBBING, Professor W. W. WATTS, and the GENERAL OFFICERS. (Drawn up by the Secretary.)

WITH the view of carrying into effect the new regulation whereby many of the smaller local Societies which exist in this country for the encouragement of the study of science may, under certain circumstances, become Associated Societies, a circular was drawn up and addressed in the early part of the year to a number of such bodies. It was found with satisfaction that some had undertaken and published original scientific work, and were consequently entitled to Affiliation. The following Societies are recommended, from the character of their published work, to be placed on the list of Affiliated Societies :—

British Mycological Society.
Edinburgh Field Naturalists' and
Microscopical Society.
Liverpool Biological Society.

Royal Cornwall Polytechnic Society.
Vale of Derwent Naturalists' Field
Club.

It is also recommended that the following be placed on the list of Associated Societies :—

Bakewell Naturalists' Club.
Balham and District Antiquarian and
Natural History Society.
Barrow Naturalists' Field Club and
Literary and Scientific Association.
Battersea Field Club.
Bradford Natural History and Micro-
scopical Society.
Catford and District Natural History
Society.
Dover Sciences Society.
Dunfermline Naturalists' Society.

Ealing Scientific and Microscopical
Society.
Grimsby and District Antiquarian and
Naturalists' Society.
Hampstead Scientific Society.
Hastings and St. Leonards Natural
History Society.
Ipswich and District Field Club.
Lancashire and Cheshire Entomolo-
gical Society.
Lewisham Antiquarian Society.
Liverpool Microscopical Society.

Liverpool Science Students' Association.

London: City of London Entomological and Natural History Society.

London: North London Natural History Society.

London: South London Entomological and Natural History Society.

Newcastle-upon-Tyne Literary and Philosophical Society.

Penzance Natural History and Antiquarian Society.

Preston Scientific Society.

Scottish Microscopical Society.

Southport Society of Natural Sciences.

Teign Naturalists' Field Club.

Torquay Natural History Society.

Tunbridge Wells Natural History and Philosophical Society.

Warrington Field Club.

Watford Camera Club.

It is further recommended that the following Societies, which had been struck off the list of Corresponding Societies through temporary non-compliance with the rules, be now reinstated as Affiliated Societies:—

Brighton and Hove Natural History Society.

Dumfries-shire and Galloway Natural History and Antiquarian Society.

Isle of Man Natural History and Antiquarian Society.

Much consideration has been given by the Committee to the subject of railway-fares, in order to ascertain whether any steps could be taken to secure reduced rates under certain circumstances for members of the Corresponding Societies. Considering, however, the number of railway-companies which would have to be approached and the diversity of local arrangements, it has been felt to be impossible for the British Association to deal with the subject as a whole. Societies which desire concessions should therefore apply directly to the railway-companies of their respective districts for such privileges; and with the view of strengthening such applications the Council of the British Association, on the recommendation of the Corresponding Societies Committee, have authorised the issue of a form of Warrant to all Corresponding Societies which send representatives to the Annual Conference of Delegates, certifying that the Societies in question are recommended by the Council as suitable applicants for any privileged tickets that the railway-companies may grant. These warrants may be obtained at the present Conference, or at the Offices of the British Association.

The Annual Schedule has been issued, as usual, to all the Affiliated Societies, and the Committee have thus obtained particulars of their work. The Manchester Microscopical Society report that they make a special feature of giving to their members demonstrations on the construction of the microscope and on microscopic manipulation. Very few Societies offer suggestions for subjects to be brought forward at the Conference of Delegates.

The Committee have decided that the following subjects shall be discussed at the Conference at York:—

The Desirability of promoting County Photographic Surveys; to be introduced by Mr. W. Jerome Harrison.

Meteorological Observations by Local Scientific Societies; to be introduced by Dr. H. R. Mill.

Other subjects may be introduced if time allows.

The Committee ask to be reappointed, with the addition of the name of Sir Edward Brabrook, and they apply for a grant of 25*l.*, with permission to retain the small unexpended balance from last year. It may be

pointed out that the British Association, by its relationship with the Corresponding Societies, is gradually accumulating a collection of the publications of the local Scientific Societies of the country, which is of exceptional value and probably unrivalled. The cost of binding the volumes is defrayed out of the grant to the Committee.

*Report of the Conference of Delegates of Corresponding Societies
held at York, August 2 and 7, 1906.*

Chairman	.	.	Sir Edward Brabrook, C.B., V.P.S.A.
Vice-Chairman	.	.	John Hopkinson, F.L.S., F.G.S.
Secretary	.	.	F. W. Rudler, I.S.O., F.G.S.

The following Corresponding Societies nominated Delegates to represent them at the Conferences. The attendance of the Delegates is indicated in the list by the figures 1 and 2 placed in the margin opposite to the name of each Society, and referring respectively to the first and second meetings. Where no figure is shown it will be understood that the Delegate did not attend. The attendances are taken from the attendance-book, which each Delegate is expected to sign on entering the meeting-room.

List of Affiliated Societies sending Delegates.

1	2	Andersonian Naturalists' Society	.	.	M. B. Gilmour, F.Z.S.
1		Bath Natural History and Antiquarian Field Club.	}		Rev. C. W. Shickle, M.A.
		Belfast Natural History and Philosophical Society.			
		Belfast Naturalists' Field Club	.	.	Prof. Gregg Wilson, D.Sc.
		Berwickshire Naturalists' Club	.	.	A. H. Evans, M.A.
1	2	Birmingham and Midland Institute Scientific Society.	}		W. Rosenhain, B.A.
		Birmingham Natural History and Philosophical Society.			
1		Bristol Naturalists' Society	.	.	Prof. S. H. Reynolds, M.A.
1		British Mycological Society	.	.	Miss Annie Lorrain Smith, F.L.S.
		Buchan Field Club	.	.	J. F. Tocher, F.I.C.
		Caradoc and Severn Valley Field Club	.	.	Prof. W. W. Watts, F.R.S.
1		Cardiff Naturalists' Society	.	.	Prof. W. S. Boulton, B.Sc.
		Chester Society of Natural Science, Literature, and Art.	}		F. W. Longbottom, F.R.A.S.
		Cornwall, Royal Polytechnic Society			
1		Croydon Natural History and Scientific Society.	}		W. F. Stanley, F.G.S.
	2	Dorset Natural History and Antiquarian Field Club.			
		Dublin Naturalists' Field Club	.	.	Prof. Grenville Cole, F.G.S.
		East Kent Scientific and Natural History Society.	}		A. S. Reid, M.A.
		Eastbourne Natural History Society			
1	2	Edinburgh Field Naturalists' and Microscopical Society.	}		W. C. Crawford.
		Edinburgh Geological Society			
1	2	Essex Field Club	.	.	F. W. Rudler, I.S.O.
1	2	Glasgow Geological Society	.	.	Prof. J. W. Gregory, F.R.S.
1	2	Glasgow Natural History Society	.	.	James Murray.
1	2	Halifax Scientific Society	.	.	W. Simpson, F.G.S.

1	Hampshire Field Club and Archæological Society.	} W. Dale, F.S.A.
1 2	Hertfordshire Natural History Society and Field Club.	} John Hopkinson, F.L.S.
1 2	Holmesdale Natural History Club .	Miss Ethel Sargent, F.L.S.
1	Hull Geological Society	J. W. Stather, F.G.S.
1 2	Hull Scientific and Field Naturalists' Club.	} T. Sheppard, F.G.S.
2	Institution of Mining Engineers . . .	J. A. Longden, M.Inst.C.E.
1 2	Isle of Man Natural History and Antiquarian Society.	} J. Kewley, M.A.
	Leeds Geological Association	Prof. P. F. Kendall, M.Sc.
1 2	Leeds Naturalists' Club and Scientific Association.	} H. C. Marsh.
1	Leicester Literary and Philosophical Society.	} Herbert Ellis.
1	Liverpool Engineering Society	Dr. H. S. Hele-Shaw, F.R.S.
1	Liverpool Geographical Society	Capt. E. C. Dubois Phillips.
	Liverpool Geological Society	J. Lomas, F.G.S.
	London: City of London College Science Society.	} J. Logan Lobley, F.G.S.
1	London: Quekett Microscopical Club .	C. F. Rousselet.
1	Manchester Geographical Society . . .	J. Howard Reed.
1 2	Manchester Geological and Mining Society.	} Wm. Watts, Assoc. M.Inst.C.E.
	Manchester Microscopical Society . . .	F. W. Hembry, F.R.M.S.
	Manchester Statistical Society	Prof. S. J. Chapman, M.A.
1	Norfolk and Norwich Naturalists' Society.	} F. Balfour Browne, M.A.
	North Staffordshire Field Club	J. T. Stobbs, F.G.S.
1	Northamptonshire Natural History Society and Field Club.	} Beeby Thompson, F.G.S.
1	Northumberland, Durham, and Newcastle-upon-Tyne Natural History Society.	} N. H. Martin, F.R.S.E.
	Nottingham Naturalists' Society	Prof. J. W. Carr, M.A.
1 2	Paisley Philosophical Institution . . .	John Woodrow.
1	Perthshire Society of Natural Science .	H. R. Mill, D.Sc.
1 2	Rochdale Literary and Scientific Society.	} J. R. Ashworth, D.Sc.
1	Somersetshire Archæological and Natural History Society.	} F. J. Clark, F.L.S.
1 2	South-Eastern Union of Scientific Societies.	} Rev. R. Ashington Bullen, B.A.
	Southport Literary and Philosophical Society.	} A. H. Garstang.
	Tyneside Geographical Society	Herbert Shaw, B.A.
1 2	Warwickshire Naturalist and Archæologists' Field Club.	} W. Andrews, F.G.S.
1 2	Woolhope Naturalists' Field Club . . .	Rev. J. O. Bevan, M.A.
1	Yorkshire Geological and Polytechnic Society.	} Wm. Simpson, F.G.S.
1 2	Yorkshire Naturalists' Union	T. Sheppard, F.G.S.
	Yorkshire Philosophical Society	Dr. Tempest Anderson.

List of Associated Societies sending Delegates.

1	Bakewell Naturalists' Club	E. M. Wrench, F.R.C.S.
1	Balham and District Antiquarian and Natural History Society.	} Sir Edward Brabrook, C.B.
1 2	Dunfermline Naturalists' Society . . .	R. Somerville, B.Sc.
	Ealing Scientific and Microscopical Society.	} Dr. W. Deane Butcher.

1	2	Grimsby and District Antiquarian and Naturalists' Society.	}	O. T. Olsen, F.L.S.
1	2	Hampstead Scientific Society . . . Hastings and St. Leonards Natural History Society.		}	F. W. Rudler, I.S.O. T. Parkin, M.A.
1	2	Lewisham Antiquarian Society . . .			A. E. Salter, D.Sc.
1	2	Teign Naturalists' Field Club . . .		P. F. S. Amery.
1		Torquay Natural History Society . . .		A. Somervail.
1	2	Watford Camera Club		John Hopkinson, F.L.S.

First Meeting, August 2.

The Meeting was presided over by Sir Edward Brabrook, C.B. The Corresponding Societies Committee was represented by Mr. Whitaker, F.R.S., the Rev. J. O. Bevan, the Rev. T. R. R. Stebbing, F.R.S., Dr. H. R. Mill, Mr. J. Hopkinson, and Mr. Rudler.

Chairman's Address. By Sir EDWARD BRABROOK, C.B., V.-P.S.A.

It is my privilege to open the proceedings of this meeting, which is the twenty-second Conference of Delegates of Corresponding Societies of the British Association for the Advancement of Science, and the first at which associated as well as affiliated Societies are represented. I am much honoured by having been selected by the Corresponding Societies Committee and appointed by my colleagues of the Council to occupy the chair of the Conference in the present year; and I anticipate great advantage from the new departure, alike to the Societies which are here brought into union and to the Association. I am myself the representative of one of the Societies which are now for the first time permitted to be associated with you—a Society so small that it was barely able to qualify for that honour by the possession of fifty members, but yet one which has been able, in the few years of its existence, to justify that existence by stimulating in the neighbourhood where I reside an interest in antiquities and in natural history, and by the publication of a paper by the late Mr. T. W. Shore bearing upon those subjects, with especial relation to local affairs. I have also the pleasure of welcoming here, in the person of Dr. A. E. Salter, the representative of another such Society, which has existed for twenty-one years, and has produced many excellent publications, and of which I had the honour to be its first and am again its present President. I cannot but feel, therefore, very great interest in the new arrangements by which these useful but modest Societies have been brought into line with those more important and more ambitious ones which have hitherto been recognised as the Corresponding Societies of the British Association.

The work of those Societies, especially in relation to Section H, has been watched by me with very great satisfaction. At the Edinburgh meeting in 1892 I read before that Section a paper on the Organisation of Local Anthropological Research, which was published in the 'Journal of the Anthropological Institute' for February 1893. At that time these Conferences and the Corresponding Societies Committee had been in operation for eight years. From the materials supplied by the reports of that Committee I sought an answer to the question, What had local Societies then already done for anthropology? and I obtained the information that during the eight years—1885 to 1892—as many as thirty-three local

Societies had been engaged in valuable, original, anthropological work, and at least a hundred individuals had contributed anthropological papers to their 'Transactions.' They occupied the whole country from Penzance to Inverness, and from Rochester to Belfast. During each of the twenty-one years I have published an answer to the same question in the form of a brief note on that portion of the annual report which relates to Section H. On more than one occasion I have had the honour of attending your Conferences as a representative of Section H, and of addressing you on one or other of the movements which have interested that Section. Though I have not until now been a member of your body, I may claim that I have been from the very first in close touch with you, and a sincere admirer of the excellent work which is done in all parts of the country by the local scientific Societies and Field Clubs.

I hope we shall find in the course of our Conference that the affiliated and associated Societies are alike capable of useful work in connection with the sciences which are cultivated in all or nearly all the Sections ; but I will not attempt in these opening remarks to go beyond the three Sections, F, H, and L, in which I am personally interested. I have no commission from the Organising Committee of Section F to lay before you any special problem of economic science ; but when I consider how wide is the range of subjects bearing upon the welfare of mankind with which that Section has to deal, and at the same time how complicated are the local considerations which affect them, I cannot but recommend to your attention the great advantage which may be derived from local investigation. To take one subject only which has recently acquired great importance, that of the unemployed workman. It is obvious that that is a subject which ought not to be dealt with upon general principles without careful local investigation, in all parts of the country, of the processes which make for mobility of labour and of all the other elements of the problem.

It is thought by many that the establishment of labour exchanges in correspondence with one another all over the country would tend to a solution of the difficulty ; but no such general scheme could be set on foot without careful consideration of the economic position of every locality. Accurate statistics of the number employed in each branch of industry and of the demand for labour and a precise estimate of the reserve of labour required to meet occasional calls would have to be obtained, and could only be made complete by enlisting the co-operation of local scientific men.

Other great economic questions which occasionally come to the front, and are treated by the ordinary statistician upon broad general lines, acquire an altogether different aspect when examined in detail in their application to a particular locality. The questions of population which emerge upon any general census, the important consideration of the decline in the birth-rate, with all the moral and economic consequences that it implies, the rate of infant mortality, the increase in the employment of women, are all matters which affect one locality differently from another, and therefore call for local treatment.

With regard to Section H what I have already said may sufficiently exemplify the special work of local Societies. Each locality has its own ancient monuments, its own relation to past history, its own mixed population, with special racial affinities ; its own ancient customs, some of their roots going far down into the past ; its own folklore, its own dialect, its own place-names ; and thus every local Society has an interest

in working out for itself its own anthropology. If it is the fact, as it seems to be, that the course of legislation and of events in the past century has been to efface as much as possible the traces of special local history and custom, and by centralisation to reduce us all to a sort of uniformity, it is all the more necessary that local Societies should place on record all these evidences before they finally disappear. It is only the local Societies by which this can be done; no bureau of ethnography could succeed in its mission without their help. By the collection of typical photographs of individuals belonging to families long settled in the district, by the recording of anthropometric measurements and otherwise, local Societies may provide precious material for the anthropologist which no central organisation could procure.

Passing on to Section L, is it not the vice of all legislation upon education that it seeks to reduce it to a uniform system, regardless of the local conditions? Have we not for years been accumulating code upon code, syllabus upon syllabus, with the view of making educational proceedings uniform all over the country? And is not that precisely the wrong way of setting to work? Why should not boys in a seaport town be taught seamanship; boys in a business town, bookkeeping; boys in a manufacturing town, mechanics; boys in an agricultural district chemistry? Why should not an ample discretion be left to every local educational authority? Possibly the answer is that the local educational authorities as at present constituted are as wooden as the Board of Education itself. Why, then, not constitute proper educational authorities? And where better can you find educational authorities than among the scientific men of the locality?

In this connection I wish to take the liberty of drawing the attention of the delegates to the International Congress on School Hygiene, which is to be held in London from August 5 to August 10, 1907. It is the second of a series of congresses, the first of which was held at Nuremberg in the Easter of 1904. That congress was attended by about 1,500 representatives, drawn from almost every civilised state, and its proceedings are recorded in four volumes. I am assured that its influence has already made itself felt in many countries in the literature, laws, and regulations connected with health and education. The forthcoming congress has already been honoured by the patronage and active sympathy of His Majesty King Edward VII., and by the official recognition of many colonial and foreign governments, and there is room to expect that it will be as numerous attended and as successful in every respect as was the Nuremberg Congress. The important bearing that the healthy surroundings of childhood in school-life have on the welfare of the country and the future of its population will, I am persuaded, be argument sufficient to ensure the interest of the members of the British Association and its Corresponding Societies in this movement.

So far I have been suggesting work for local Societies and incidentally urging the necessity for such organisations, but, as you are here to represent them, it is presumed you are already convinced of that necessity, and to urge it further would be to preach to the converted. I pass on, therefore, to the next point: Why should the local Societies correspond and be affiliated and associated? What is included in the two ideas, affiliation and association, which we are now working out together for the first time? Let me say at once what I think is not included in them. No sinking of the individual character of any local Society is so included.

The affiliation which creates the Association our putative father does not give it the right to enforce our obedience to its commands or its caprices by any system of parental discipline any more than it implies that the Association will be responsible for our maintenance. If we are children we are emancipated children, earning our own subsistence and going our own way. To drop the metaphor, I assert that it would be idle for this Conference to attempt to lay down any hard-and-fast lines which every Corresponding Society must follow.

Within its legitimate province, however, there is much that this Conference can do, much that these Conferences have already done. In the free communication with each other which is here set up, in the discussion of methods of working, in pointing out special subjects in which definite and organised investigation is desirable, in learning what has been done by such and such a Society, so as to avoid wasteful duplication and repetition of work, there is ample material for conference. In the excellent relations which such meetings as these create between those who are engaged in the like pursuits and actuated by the same ambitions there is an element of great value. 'Iron sharpeneth iron; so a man sharpeneth the countenance of his friend.' We who are now admitted to be your associates, whose highest claim is that our Societies are 'formed for the purpose of encouraging the study of science,' will leave this Conference, I am persuaded, more than ever stimulated to do our utmost to fulfil that purpose.

At the conclusion of the Chairman's Address, the Report of the Corresponding Societies Committee was read by the Secretary. It was resolved to apply for a grant of 25*l*.

Mr. W. Dale (Hampshire Field Club and Archæological Society) explained the method adopted by his Society for obtaining railway tickets at reduced rates for members attending the field-meetings.

Mr. Edward Kitto (Royal Cornwall Polytechnic Society), after expressing appreciation of the honour conferred upon his Society by being placed on the list of affiliated Societies, reminded the Conference that the Royal Cornwall Polytechnic Society was the first 'Polytechnic' instituted in the country. The most important permanent work of the Royal Cornwall Polytechnic Society was the carrying on of the Falmouth Meteorological and Magnetical Observatory. The Meteorological Observatory was one of the seven first-class observatories established in 1867 by the Meteorological Committee of the Royal Society, under whose control it had remained to the present time. The Magnetical Observatory started regular records of magnetic declination and of horizontal and vertical force in 1887 with a set of self-recording magnetographs furnished by the Royal Society. That branch of the Falmouth Observatory work was at present extremely important. The magnetic records at Kew Observatory were in measure vitiated by the effect of electric trams in the neighbourhood, and as a consequence their results have not of late been published in complete form. The Falmouth magnetographs—happily not so interfered with—were in full working order and furnished complete returns whereby the continuity of magnetic records for the Kingdom was maintained. Mr. Kitto said he would venture to promise that his Committee would be prepared to present to the Association a fairly complete set of the annual reports of the Royal Cornwall Polytechnic Society from its inception in 1833.

Dr. Hugh Robert Mill introduced the following subject : --

Local Societies and Meteorology.

The study of meteorology may be commended to the attention of those scientific Societies whose scope is wide, on account of the means it affords of advancing science and at the same time obtaining those intellectual advantages to the student which it is one of the objects of scientific Societies to secure. The object of studying meteorology is not to fit the student to predict the weather of to-morrow, though it may help him to stimulate the Meteorological Office to keep improving the weather forecasts by bringing intelligent criticism to bear on the forecasts as issued. These forecasts receive criticism enough at present, but too often of a captious and uninstructed kind which contains neither correction nor help. The main object is to advance meteorology by means of careful and accurate observation. Thousands, perhaps even millions, of observations have been made and recorded in the past absolutely uselessly, for the instruments have been untrustworthy, the hours of observation irregular, or the records rendered valueless by not being communicated to the authorities competent to deal with them.

The best advice which can be given to an enthusiast anxious to observe is not to begin until he has good instruments certified as accurate. In a long record the difference in the cost of good and bad instruments is almost nothing when compared with the value of the observer's time lavished upon work which a few shillings spent at the outset makes permanently valuable, a few shillings saved makes useless or even harmful.

There is scope in meteorology for a great diversity of work. Definite researches should be carried on in specific directions. At present the most interesting and perhaps the most important of these is the investigation of the free air at great heights by means of instruments raised by kites. Excellent work is being done in this country by a joint committee of the British Association and the Royal Meteorological Society, which has been greatly aided by the inventive genius and generous help of Mr. W. H. Dines. Additional centres for kite work are desirable, but these must be remote from the haunts of men, as the accidental fall of a kite with several miles of steel wire attached is a very serious risk near towns or thoroughfares. The equipment costs about 150*l.* and the work demands great mechanical skill.

Another research which awaits the student is that into the measurement of moisture in the air, and the revision of the tables by means of which the humidity is calculated from readings of the dry and wet bulb thermometers.

A more simple and no less useful department is the study of local climate, and here the co-operation of local societies may be confidently invited. Every important town should have a properly equipped meteorological station. An observatory such as that maintained at Falmouth by the Royal Cornwall Polytechnic Society is beyond the resources of most Societies ; but a Second Order station, where the instruments only require attention for a few minutes twice daily, such as that in the Museum Garden at York, is within the reach of most. The climate of a place can only be determined by a long record, and such records are very rare, because on the death of an enthusiastic observer there is

frequently no successor to carry on the work ; and a gap once made, though not fatal to some uses of a record which has been re-established, deprives it of much of its permanent value. If such a record were under the charge of a Society, which by its nature is immortal, it should go on continuously, ever growing in value. Anyone wishing to start such a station will find full particulars very clearly set forth in Mr. W. Marriott's 'Hints to Meteorological Observers,' a little book published by the authority of the Royal Meteorological Society. That Society is always ready to encourage the study of meteorology, and has recently made arrangements to co-operate with local Societies by providing lectures and exhibitions of instruments, full particulars as to which may be obtained from the Secretaries at 70 Victoria Street, London, S.W.

Two of the elements of climate stand in particular need of additional study, and to these attention might profitably be given by all scientific Societies whose aim is not restricted to the study of one department. The first is sunshine. The duration of sunshine is measured best by an instrument known as the Campbell-Stokes sunshine recorder, the records of which are accepted as authoritative by the Meteorological Office and the Royal Meteorological Society, to one or other of which the records should be sent for accurate measurement and preservation. There is at present no such thing as an accurate map of the average annual duration of sunshine in the British Isles, and yet both in relation to agriculture and to health it is a condition of great importance.

The second element of climate for which additional observations are necessary is rainfall. While a few hundred stations uniformly distributed over the country would supply all the information necessary with regard to temperature, pressure, or wind, which vary gradually from place to place, the extraordinary influence exercised by local conditions of configuration of the land upon rainfall makes it necessary to have several thousand well-distributed stations in order to study the rainfall fully. There are 4,000 rainfall stations at present at work in the British Isles, but they are not uniformly distributed, and so it happens that while some localities are amply supplied others are almost neglected. The perfect arrangement would be to have a network of stations at most five miles apart, and to secure continuity at each five-mile centre there should be two or even three stations within half a mile of each other. If this were secured it would be possible to take account not only of the general rainfall of the country, but also of the limits and intensity of every heavy shower, the incidence of which is often curiously restricted. A map was exhibited showing the districts in which additional rainfall-stations are most urgently wanted. While these are most numerous in the Highlands of Scotland and the West of Ireland there are large areas in the East and North Ridings of Yorkshire where a large increase in the number of stations would be very welcome.

It is desirable that all rainfall-observers should be in touch with the British Rainfall Organisation, under the direction of the reader of this communication, at 62 Camden Square, London, N.W. ; there is at the same time room for local associations of observers under the supervision of local scientific Societies, which should be charged with seeing that proper instruments are used when a new station is started, with the provision of successors when old observers cease to record, and with the establishment of new records in places where none exist.

Apart from the stations provided by the Meteorological Office in

various parts of the British Isles, by the Royal Meteorological Society in England, and by the Scottish Meteorological Society in Scotland, rainfall stations are supervised and the records published by the following Societies :—

Croydon Natural History and Scientific Society.—102 stations in north-western Kent and eastern Surrey.

Dorset Field Club.—48 stations in Dorset.

Hertfordshire Natural History Society.—55 stations in Herts.

Northamptonshire Natural History Society.—41 stations in Northamptonshire.

North Devon Athenæum (Barnstaple).—30 stations in North Devon and Somerset.

Rainfall associations are also organised by individuals in Cambridgeshire and Huntingdon, Norfolk, the English Lake District, the Isle of Man, Mid-Wessex and Stirlingshire.

Mr. J. Ferguson (Ceylon) inquired what period of years Dr. Mill would fix as the minimum for continuous rainfall observations to prove of practical value from a scientific point of view. In Ceylon, and in most tropical planting colonies, superintendents of plantations were accustomed to include attention to the rain-gauge (and sometimes to thermometers) as part of their daily duties; but nowadays each man had, as a rule, only a limited stay on the estate, although in pioneering days fifteen to twenty-five years' residence was not uncommon. He might point out to delegates how important it was that young men who looked for a career to farming or planting in the colonies—where there were few or no weather traditions available—should get some experience of simple meteorological observations at home.

Mr. J. Hopkinson (Hertfordshire Natural History Society) said that he would only refer to one or two points connected with Dr. Mill's remarks. (1) As to the cost of taking meteorological observations, he feared that the delegates might be deterred by thinking that it was greater than is really the case. A reliable 'Snowdon' rain-gauge, with a certificate from the Kew Observatory or from Dr. Mill could be obtained for from 20s. to 25s. For a climatological station of the Royal Meteorological Society four thermometers were also required, a maximum and minimum, and a dry bulb and wet bulb (the latter two to obtain the relative humidity of the air), and also a 'Stevenson' (louvre-boarded) screen to place them in, the cost of this equipment being, he thought, about 5*l.* or 6*l.* All the thermometers should be tested at the Kew Observatory. (2) Only one reading daily was required, at 9 A.M., when the proportion of sky covered by cloud (0-10) should be estimated. He knew from experience that all the observations required for such a station could be made in five minutes. (3) As to continuity. This was most important, and he would urge upon the Corresponding Societies to endeavour to ensure continuity of observation by getting any private meteorological observatory which seemed likely to be discontinued transferred to some institution or public body. After taking climatological observations for twelve years at Watford, and then for thirteen years at St. Albans, he transferred his own instruments to the County Museum there, instructing the caretaker how to make the observations, which he supervised, worked up, and published annually in the 'Transactions' of his Society. As the

climatological station thus established was under the trusteeship of the Hertfordshire County Council, he hoped that it would be permanent.

Dr. J. R. Ashworth (Rochdale Literary and Scientific Society), after remarking on his attempts to get a sunshine-recorder established in Rochdale, suggested that meteorological work might be promoted by carrying out a meteorological survey of the British Isles. A first step would be to ask each local Society to draw up a schedule stating what observations were being taken in its own area, the kind of instruments in use, when and how they were verified, the duration of the record, and where the results were published. Such an account might be rendered to Dr. Mill or to the headquarters of the British Association. The next step would be for the central authority to draw attention to those districts where records were non-existent or scanty, and to urge local Societies to use their influence to make good the deficiencies. It would at least be useful to have a comprehensive summary of the meteorological work carried out in each locality throughout the country.

Mr. N. H. Martin (Northumberland, Durham, and Newcastle-upon-Tyne Natural History Society) agreed with Dr. Mill that it would be well if meteorological observations were seriously undertaken, with properly equipped stations, by local scientific societies, as in this way there would be a greater probability that the records would be continuous over a period of years long enough to make them valuable. The speaker did not think it was the expense of fitting up a station of the second order which deterred private individuals from the work, so much as the tie it was to read the instruments and take the records with that punctuality which alone would give them value.

Mr. Walter Rosenhain (Birmingham and Midland Institute Scientific Society) asked how frequently it was required to read rain-gauges for the purpose of Dr. Mill's rainfall survey. Would one reading in twenty-four hours be sufficient?

Mr. E. Kitto (Royal Cornwall Polytechnic Society), referring to a former speaker's remarks as to the difficulty sometimes of procuring the services of competent observers, said that he attached first importance to reliable observers; next to trustworthy instruments authoritatively verified, and then the selection of suitable sites for the various instruments, so that the observations might be taken under satisfactory conditions; and last, but not least, to punctuality in making the observations; this was extremely important if the records taken by a great number of observers were to be comparable with one another or of service for scientific purposes.

Dr. Mill briefly replied to the discussion. In answer to Mr. Ferguson he said that while at least thirty years was necessary in this country to obtain a trustworthy average of annual rainfall, a much shorter period sufficed for the less variable climate of the tropics. As regards Dr. Ashworth's suggestion, he thought that the lists of general meteorological stations published annually by the Meteorological Office, the two Meteorological Societies, and in 'British Rainfall,' fairly covered the ground; but it would certainly be an advantage to have these reduced to a single list, indicating the nature of the work done at each station. In reply to Mr. Rosenhain, one reading in twenty-four hours, at 9 A.M., was all that was asked for in rainfall observations, and in certain circumstances gauges read even once a week or once a month were not without value.

Second Meeting, August 7.

Mr. John Hopkinson, F.L.S., F.G.S., in the Chair.

The Corresponding Societies Committee was represented by Mr. W. Whitaker, Rev. J. O. Bevan, Mr. Hopkinson, and Mr. Rudler.

The Chairman, in opening the proceedings, said that it might not be known to all who were present that a Conference of Delegates of Corresponding Societies met at York twenty-five years ago. It was not recorded in the Reports of the British Association; for, although held under the sanction of the Council, it was not an official department of the Association. It was the second of five unofficial conferences due to his suggestion, the first having been held at Swansea in 1880 and the last at Montreal in 1884. Reports of these five annual conferences were printed, the delegates or their Societies contributing towards the expense of printing and postage, and abstracts of these reports were published in the 'Transactions of the Hertfordshire Natural History Society' (vol. vi. pp. 45-47). He wished to impress upon all the delegates that they were expected to give some report, however brief, of the present Conference to the Societies they represented, and to obtain its publication by their Societies. They were asked to do so in the circulars issued by the Corresponding Societies Committee, but only a few, he believed, complied with this request. Though not bringing forward his own reports published by the Hertfordshire Natural History Society as a model to be followed, they might perhaps be a help to some of the delegates, and he had brought for distribution a few copies of these reports for the years 1902 to 1904. That for 1905 was not yet printed.

At this meeting suggestions for a Photographic Survey of the Counties of Great Britain and Ireland would be brought before the Conference by Mr. W. J. Harrison, and he thought that all would admit that this was an important subject, and one which well deserved the consideration of our county Societies. It was becoming more and more desirable to obtain a permanent representation of the interesting features of our country, whether natural or the work of man; for at no former period had the destruction or mutilation of such features been more rife, and never before had so much interest been taken in their preservation. This apparent paradox might be explained by the fact that the greater the vandalism the greater was the protest evoked. Nor should the ravages of time be overlooked, nor the changes due to natural agencies, such as the encroachment of the sea upon our coasts. The sooner the better, therefore, would it be for a systematic attempt to be made to obtain and preserve a picture of everything of interest admitting of representation by the camera in all departments of science not within the scope of any existing Committee of the Association. This could best be done by our Natural History and Archæological Societies, Camera Clubs, and Photographic Societies, and amateur photographers unattached to any Society or club, working in conjunction with some central body, such as a Committee of the British Association; for in this way only could a photographic survey be sufficiently systematic in its execution, and in this way only could comparable results of permanent value be achieved.

The Desirability of Promoting County Photographic Surveys.
By W. JEROME HARRISON, F.G.S.

I.—ORIGIN OF THE PHOTO-SURVEY MOVEMENT.

The movement which it is the object of this paper still further to promote had its origin in a meeting of the representatives of numerous local photographic, scientific, and literary societies at Birmingham in 1889, when a paper was read entitled 'Notes upon a Proposed Photographic Survey of Warwickshire.' This paper was an amplification of the ideas which had been urged in a note upon 'The Work of a Local Photographic Society,' read before the Birmingham Photographic Society in 1885, and published in the *Photographic News* (vol. xxix. p. 421).

Although this Birmingham paper of 1889 had a local title, yet it has, and was intended to have, a general application.

In response to an invitation from the (Royal) Photographic Society of Great Britain, a paper bearing the wider title of a 'Proposal for a National Photographic Record and Survey' was subsequently read before that body in London in 1892. In this paper the right and duty appertaining to the 'parent' photographic Society of taking the lead in this most important work was strongly urged.

Finally an ambitious attempt was made to link together the photographers of the entire civilised world by an extension of the 'survey' idea, and at the World's Congress at Chicago in 1893 a paper upon 'The Desirability of an International Bureau; established (1) to record, and (2) to exchange Photographic Negatives and Prints,' in which these views were explained, was read and discussed. In this paper three principal points were urged:—

(1) In every country it is desirable that a photographic survey should be initiated. By the term 'survey' is here meant a pictorial record of the state of things, physical and general, now existing.

(2) In each country there should be (a) local depôts (free libraries, museums, &c.) containing complete sets of permanent photographic prints of the immediate district; and (b) a central bureau (in England, the British Museum, for example) containing both negatives and prints relating to the entire country.

(3) Facilities for the exchange, or purchase, of prints, &c., should be provided.¹

On the motion of Mr. Snowden Ward an International Committee was appointed to consider how these ideas might best be carried out. This Committee did good work in disseminating a knowledge of the survey movement, and its French representative, M. Léon Vidal, inaugurated a very complete system in his own country.

II.—PROGRESS OF PHOTO-SURVEY WORK IN BRITAIN.

Seventeen years have elapsed since the photographers of Warwickshire began their task of making a local photo-survey. Each year an exhibition of the Warwickshire Survey Prints has been held in the Municipal Art

¹ A few copies of the first paper of 1889 still remain, and, while the supply lasts, a copy will be gladly forwarded to the secretary of any Society which contemplates commencing photo-survey work. Address: W. J. Harrison, 52 Claremont Road, Handsworth, Birmingham.

Galleries of Birmingham. The prints have afterwards been presented to the Free Reference Library, where they can be examined and studied at any time. The number of local survey photographs in the Birmingham library is 3,020 prints, bound in 110 folio volumes.

Other localities where work for the photo-survey has been commenced include Barnstaple, Cardiff, Chester, Darlington, Bromsgrove, Exeter, Manchester, Stoke-on-Trent, Wolverhampton, and Yorkshire; but we have not seen any recent reports of progress from any of these centres. The following, however, are known to be more or less actively engaged in survey work (the names given being those of the Hon. Secretaries):—

Warwickshire (Geo. Whitehouse); *Worcestershire* (W. H. Harris); *Essex* (Victor Taylor); *Kent* (J. H. Allechin); *Surrey* (F. F. Wood); *Consett Valley, Yorkshire* (P. E. Surtees); *Edinburgh* (James Burns); *National Photographic Record Association* (Geo. Scamell).

III.—OBJECTS OF PHOTO-SURVEY WORK.

The three great objects of the Photographic Record and Survey are to benefit—(a) The individual photographer; (b) the Scientific and Photographic Societies; and (c) the nation generally.

(a) *The Individual Photographer and the Survey.*—The survey scheme gives the photographer an object, and we maintain that the work of such a survey is a liberal education for any man. It is impossible to photograph without learning much about the objects photographed; and the survey brings photographers into contact with experts who are able and willing to afford ample information.

The professional photographers of the British Isles now form a small army, their number being recorded by the census of 1901 as 17,945. Many firms must possess stores of negatives illustrating 'survey' subjects; and it is certain that if properly approached the average professional of any standing would be willing to aid a county photographic survey.

Lastly, there is the great body of 'unattached' photographers, whose number can hardly be estimated, but, omitting the casual snapshotter, there are, perhaps, a quarter of a million who could do useful work for a photo-survey, if someone would only tell them what to do, and how to do it.

(b) *Photographic and Scientific Societies and the Survey.*—The total number of British Photographic Societies in the list published in the 'British Journal Almanack' for 1906 is 354. And in the 'Year Book' of the scientific and learned Societies of Great Britain and Ireland for 1905 the number of Societies other than photographic, but whose work would be more or less aided by photography, is given as 333. In addition there are many Societies connected with the 'Fine Arts' not included in either of the above lists.

It is a mistake to suppose that the task is one which appeals only to practical photographers. The man with the camera may know *how* to photograph, but it is impossible that he should always know *what* is worth photographing. For this purpose he needs the advice of an expert, and the guidance of the man with local knowledge.

To the Society, as to the individual, the duty of having a useful public task to accomplish is of great value. It binds the members together, it attracts members, and it brings the Society before the public.

(c) *The Nation and the Survey.*—The work of a photographic record

and survey is of value alike to the generation by which it is executed and to all succeeding generations.

The physical features of the land slowly alter, even if left solely to the unaided action of the forces of Nature. There are points on our eastern coast where the sea has advanced a mile or more during the last century. But when we include the agency of man we find yet more rapid alterations. Every year the amount of waste land is diminished—the bogs are drained, the pastures creep up the hill-slopes, forests vanish here, while new plantations spring up there. The opening-up of mines and quarries, the cutting of new canals and railways, the rapid expansion of our towns and cities—in all these, and in many other ways, the natural scenery of these islands is continually being changed. Then there are the noble buildings and monuments which we have inherited from our forefathers, and in which history is written in stone. Architecture is indeed one of the strongholds of photography.

It is also important that we should record the *life of the nation*—the trades, the dress, the occupations of the people, their habits and their amusements. We live in an era of unusually rapid change. The improved means of communication, the discoveries of modern science, and the spread of education all combine to abolish the differences of language, of dress, and of manners.

The British Association has rightly joined in hastening on the work of an Ethnographical Survey of the United Kingdom; for if such a survey is not done quickly, the amalgamation of the people of the different counties will have gone so far as to render the task useless, if not impossible.

IV.—‘DISTRICT’ SURVEYS AND ‘SUBJECT’ SURVEYS.

The work of a photo-survey may proceed along two distinct lines, although these may of course be pursued simultaneously:—

(a) *A District Survey*, where, say, the one-inch map or the six-inch map is taken as the unit, and *all* items of interest within that area are photographed. This is the method so far pursued by those who have approached the task from the photographic side.

(b) *A Subject Survey*, in which some definite line of research is followed. It is in this direction that the efforts of most of our men of science who are not connected directly with photography and photographic Societies have tended. No praise can be too high for the work of the Geological Photographs Committee of the British Association. The Committees on Anthropological Photographs and on Botanical Photographs are working upon similar ‘subject’ lines, while many of the other Committees largely use photography. Indeed the British Association seems to be specially well fitted to carry on the work of subject surveys.

V.—BASE OF THE BRITISH PHOTO-SURVEY.

Unquestionably the great unit for district surveys should be the *county*. For the small working unit, nothing can be better than the maps of the Ordnance Survey. The one-inch map is good; but the six-inch gives such detail that by its aid we can determine the orientation of buildings, &c., so as to be able to select beforehand the precise hour of the day when the light will be best suited for work.

VI.—PROMOTION OF THE 'SURVEY' MOVEMENT.

What can be done by the Corresponding Societies Committee of the British Association to aid the photo-survey? A small sub-committee might be appointed :—

- (a) To collect details as to the work done or being done.
- (b) To prepare and circulate printed matter on the work of the survey, so as to make its aims and methods generally known.
- (c) To co-ordinate the photographic Societies with the literary and scientific Societies, so that all may unite in the work of the survey.
- (d) To obtain lists of 'experts' in various departments, who would be willing to advise upon such subjects as photographic methods, processes, and appliances; to draw up county lists of objects and places, specifying their exact points of interest, &c.; to write brief descriptions upon the backs of the mounts, the survey prints, &c.; and to draw up lists of literature upon the counties or other areas.
- (e) The publication of series of prints either of districts or of subjects would be one of the best methods of popularising the survey.

APPENDIX.

Suggestions and Memoranda for the Use of Societies, Committees, or Sections, as to the Working of a Photographic Survey.

1. In any district, a Society, Committee, or Section may be formed, to promote the work of a photographic survey. Such a body may be either independent or part of an already existing Society.
2. Members may be of two classes—(a) Experts in photography; (b) Experts in other branches of science, literature, and art.
3. Members in class (a) who desire to join in the work of a photo-survey, must (prior to election) send in not fewer than — prints as their first contribution to the work of the survey; and must further contribute at least — prints annually. Members of class (b) must subscribe not less than — per annum.
4. All prints should preferably be by some *permanent* process, such as carbon, platinum, or bromide, but silver-prints will be accepted. Prints may be of any size. ['Half-plate,' $6\frac{1}{2}$ by $4\frac{3}{4}$ inches, or 'whole-plate,' $8\frac{1}{2}$ by $6\frac{1}{2}$ inches, preferred.]
5. Prints may be sent in either mounted or unmounted. If mounted, they must be upon 'standard' mounts. These standard mounts may be of two sizes. The first size to carry one 'whole-plate,' or two 'halves,' or four 'quarters'; the second or larger size to take prints up to 15 inches by 12 inches. Prints must be mounted behind 'cut-out mounts,' so that the surface of each print may be protected from abrasion, and they must carry printed headings or labels on their backs for particulars to be filled in by the photographer. The 'first size' mounts should measure 14 inches by 11 inches, with a central space for the prints of $10\frac{1}{2}$ inches by $7\frac{1}{2}$ inches.
6. As many details as possible must be given upon the back of the mount about each photograph, including: (1) Subject, (2) Date, (3) Time of day, (4) Focal length of lens, (5) Printing process, (6) General remarks, (7) Contributor's name and address.

7. The officers of the survey shall include a *Curator*, whose duties shall consist of the care, classification, cataloguing, mounting, &c., of the prints; and a *Secretary*, to conduct the correspondence, &c.

[A Chairman and a Special Survey Committee may also be necessary.]

8. Beyond simple 'spotting,' it is not advisable that any 'retouching,' 'improving,' or 'double-printing' should be done to the negatives from which prints are to be taken, or to the prints themselves.

9. The work of a photo-survey established under this scheme is intended to supplement, and not in any way to interfere with, the work which is already being done in this direction by other photographic or scientific Societies.

10. Many districts are not covered by the existing photographic Societies; many individuals who are not connected with such Societies are willing and able to do survey work, and there are many lines of research which are best conducted by specialists working alone. The Survey General or Central Committee will endeavour to cover such districts and to enlist and direct the services of isolated workers and specialists.

11. Information will be sought as to buildings, places, or regions in which restorations, destructions, or great changes are likely to occur.

Lists of such buildings, &c., have already been compiled by Mr. Snowden Ward and published in the 'Monthly Photogram.'

12. Lists of special areas for photo-survey work and of special lines of inquiry shall be drawn up and circulated. Suggestions are asked for.

Examples (a) of neglected (or unsupplied) areas such as—

- (1) Salisbury Plain, Dartmoor, the New Forest, &c.
- (2) The Scilly Isles.
- (3) The Fens.
- (4) Many isolated districts in Wales, Ireland, and Scotland.
- (5) The coastline generally (to show the effects of erosion).
- (6) The Roman Roads.
- (7) North Lincolnshire (before the development of the recently discovered coalfield changes the entire character of this agricultural district).
- (8) The South Staffordshire coalfield—an area where the coal seams will probably be worked out ere the close of another quarter-century.

And (b) of special lines of inquiry, as—

- (1) Occupations (trades, &c.) of the people.
- (2) Dress as influenced (i) by occupation, (ii) by 'fashion.'
- (3) The native flora of Britain—wild plants photographed in their natural habitats.

13. The survey may hold at least one meeting annually for the purpose either of making a more or less complete photo-survey of some (photographically) neglected or specially interesting district; or of co-operating with some existing Society or Societies in inaugurating or extending such a survey.

14. Sample sets of mounts, maps, illustrative survey-photographs, &c., shall be prepared. Of these sample sets, one set shall be kept for reference at the office of the survey, while the other may be borrowed by any Society or member, who must, however, defray the cost of carriage both ways and return the set whenever requested to do so by the Hon. Secretary.

15. Of the photographs collected, the first complete set shall be deposited in some public institution (preferably the British Museum).

Sets of survey photographs of local interest may also be presented to any local institutions (as free libraries and museums) which may be willing and able to take proper care of them.

16. If not fewer than — members apply, a special sub-section or sections may be formed, among whom a portfolio of survey prints (with accompanying descriptive note-books) shall circulate. Such members shall pay a small annual subscription to defray extra expenses.

17. The inauguration and direction of photo-survey work in the British Colonies may be one of the objects of the survey.

18. Photography *at sea*, including meteorological phenomena, types of vessels, of seamen, waves, icebergs, marine animals and plants, &c., may be one of the special subjects of which records shall be obtained. Photographs taken by British travellers in unexplored, wild, barren, or savage regions of the earth, such as the Polar Regions, Central Africa, &c., may also be included in the survey collections.

19. An annual exhibition of the work of the survey may be held.

20. The gift of negatives, as well as of prints, is solicited.

21. Local photographic, literary, scientific, archæological, and art Societies may be affiliated to the survey. Such Societies may aid in the preparation of lists of objects and places for the work of the photo-survey; and by the help of their members as local guides and experts.

22. The survey may appoint a professional photographer or photographers to do the work of printing, both for the survey and for individual members.

23. In any lists of the members of the survey which may be published the number of prints contributed by each member shall be shown (in brackets) after his name.

24. *Apparatus*.—The following specification refers to a set of apparatus which has been used for survey-work for several years past:—

(1) Half-plate camera fitted with turn-table and behind-lens shutter. (2) Three double plate-holders, with pull-out aluminium slides. (3) Three-fold wooden tripod. (4) Wide-angle lens (anastigmat), $5\frac{1}{2}$ inches focus. (5) Lens (anastigmat) for ordinary work, $8\frac{1}{2}$ inches focus. (6) Changing-bag and focussing-cloth combined. (7) Spirit-level. (8) Focussing-glass. (9) Yellow screen (for orthochromatic plates). (10) Note-book and exposure meter. (11) Stiff brown canvas carrying-case. (12) Ordnance map of the district. The weight of such an outfit (loaded with six glass plates) will be 14 lb.

25. The 'half-plate' is perhaps the smallest size which gives, in itself, a useful print; and yet it is not too big for the enlarging apparatus. Enlargements to 23 by 17 inches are to be preferred for wall-pictures.

26. To get good enlargements we must use lenses capable of giving fine definition, and the lenses recommended are most satisfactory in this respect.

27. *Plates* are to be preferred to *films*, because of their possessing a plane surface, which can be relied on to be in register with the focussing-screen, and for their rigidity, although films possess the advantages of lightness, non-breakability, and ease of storage.

28. Each member shall be furnished with a ticket or book stating that he is a member of the photo-survey, and giving brief particulars of

the survey work. Endeavours shall be made to obtain a reduction of railway fares to bearers of such tickets when carrying photographic apparatus, and also to obtain permission to photograph (as in cathedrals and public places generally) on production of such a ticket.

The Rev. J. O. Bevan (Woolhope Naturalists' Field Club) asked leave to take part in the discussion on the score that for many years past he had felt a great interest in the subject. He adverted to the pains taken in the preparation of Mr. Harrison's paper and to the value of the information conveyed. He considered, however, that the Appendix, dealing with details, was premature, inasmuch as the principle of a photographic survey had not yet been affirmed by the British Association, and as there was some doubt whether it would be considered by the Council to come within the scope of their operations. Of course the projected survey had an important and a special value of its own; but many of the objects represented (whilst possessing an artistic or historical value) might not illustrate any ethnological or anthropological fact or principle, and it was with the scientific aspect alone that the British Association was concerned. Assuming a scientific value, would it not be well to ascertain what materials already existed for a complete survey, and to join hands with bodies which had already undertaken any department of a similar work? The Society of Antiquaries had projected an archæological county index and map of England and Wales, the special objects placed on the index being plotted on the map in symbolic form and characteristic colour. Several of these maps had been completed. The speaker himself was responsible for that relating to Herefordshire and in a *brochure* published a few years ago had advocated an extension of the scheme in the following words: 'Could not Archæological Societies, in conjunction with this agency, startle the world with an illustrated index and map? This would be of immense interest—an interest that would increase in geometrical ratio from year to year. The expense would naturally be great, but would be considerably lessened by the fact that many woodcuts even now would be available from their "Transactions" and elsewhere.'

It was evident that such an inclusive index as that already published for some half-dozen counties would furnish a basis for a general photographic survey, and it were much to be wished that the whole series might be completed. Again, certain publishers were bringing out a Victorian County History of England, and the speaker had approached them with a suggestion that such an archæological index should be included in each volume. Further, various Societies existed with a kindred aim, such as the National Photographic Record Society; but the work undertaken by such bodies, though extremely interesting, was frequently discursive and fragmentary, as opposed to any British Association scheme, which would be systematised on a progressive and regular plan.

Probably it would be found that, in almost every county, photographic survey work had been carried on, such as that so effectively executed in Yorkshire and Warwickshire. The need for such action became increasingly evident as time rolled on. A central advisory authority was needed to supply information as to what had been done and what remained to be done, to act as a clearing-house between local Societies and the Association, to lay down certain simple rules in order to ensure uniformity, and, finally, to stimulate a general and strictly scientific interest in the matter.

If Mr. Harrison's suggestions were to be efficiently and rapidly carried out, the speaker could not conceal from himself the enormous amount of work to be done and the practical difficulties in the way. It would almost seem to need an independent Society, a central home, a depository for completed work, a secretary, and a grant for office expenses. He begged the Delegates to remember the magnitude of the subject, and suggested that the discussion should deal with the principle involved, rather than with the mass of detail which had occupied the second part of the paper.

Mr. T. Sheppard (Yorkshire Naturalists' Union) thought that the difficulties to be surmounted were, perhaps, not quite so serious as had been suggested by the previous speaker. Already the British Association, with its Geological Photographs Committee, was doing excellent work as regards geological photography. He believed also that there was a Botanical Survey Photographs Committee and an Ethnographical Committee doing similar work. If the various Societies affiliated with the British Association made up their minds to set to work, as the Geological Section had done, good would result. If, however, the matter was allowed to drop so soon as this Conference was over, it was useless to approach the General Committee for a grant or for anything else. In Hull the photographic Society had already done good work by taking careful photographs of the local archaeological and architectural features, which were sent to headquarters, while a duplicate set was placed in the public museum.

The Rev. R. Ashington Bullen (South-Eastern Union of Scientific Societies) said that there were now three County Photographic Surveys affiliated to the Union which he represented—viz. those of Surrey, Kent, and Sussex. A much appreciated feature of the Annual Congress of the S.E. Union was the yearly exhibition by the above-named surveys of the photographs taken during the previous year. It appealed to many different intellectual tastes, and he thought that during a British Association meeting an exhibition by the particular survey of the county in which the meeting was being held would be an added attraction, and would appeal to the varied interests of the members.

Mr. W. F. Stanley (Croydon Natural History and Scientific Society) suggested that the most convenient size for photographs of interest was quarter-plate, as these might be taken with the kodak commonly carried by members of local Societies. Also that films (which were now made very imperishable) were light, and easily stored without risk of breakage. These were valuable for producing lantern-slides for lectures or enlargements. Some lantern-slides of Old Croydon, taken in this manner by Mr. Low Sargeant twenty-five years ago, were unique, and had become very valuable for reference.

Professor H. H. Turner (Oxford) remarked that the value of survey photographs would be greatly enhanced if they could be taken on the stereoscopic plan, from two points of view. Such pairs of photographs would provide material for making a ground-plan of the objects photographed. The measurements and calculations were very simple: he begged leave to refer those interested to a paper of his own 'On a Simple Method of Accurate Surveying with an Ordinary Camera,' in the Monthly Notices of the Royal Astronomical Society, vol. lxii. p. 126 (December 1901).

Mr. Rudler (Essex Field Club) desired to call attention to the excellent work being done by the 'Photographic and Pictorial Survey and Record 1906.

of Essex.' This organisation was started only last year by the Essex Field Club, at the suggestion of Mr. A. E. Briscoe, but it has already formed the nucleus of a collection of permanent photographs, engravings, maps, &c., which promises to be of much value to the future naturalist and historian of the county. The collection is preserved in the Essex Museum at Stratford, and contributions of suitable photographs should be sent to Mr. Victor Taylor, of Buckhurst Hill, hon. sec. of the survey.

Dr. H. R. Mill wrote: The great obligation which all interested in photographic records owe to Sir Benjamin Stone and to the National Photographic Record Society, of which he is the president and most active member, ought not to be lost sight of on this occasion. The rules adopted by that Society and the method of its organisation seem to me to leave little to be desired. The work, although incomplete, is by no means un-systematic, and the fact that the records are deposited in the British Museum makes it national in more than name. Reference should also be made to the admirable work of the London County Council in making the photographing of all buildings before demolition part of its ordinary routine.

The Chairman suggested that an application should be made at next year's meeting of the British Association to secure the appointment of a Committee for County Photographic Surveys. After some discussion the following were provisionally nominated as members of such a Committee: Rev. J. O. Bevan, Mr. John Brown, Rev. Ashington Bullen, Mr. W. Croke, Mr. W. Jerome Harrison, Mr. T. Sheppard, Sir J. Benjamin Stone, and Mr. W. Whitaker.

Reports from the Sections.

The Chairman then invited any Delegates from the Sections who were present to explain how the Corresponding Societies could assist in aiding the work of the several Sections.

Professor H. H. Turner, representing Section A (*Mathematics and Physics*), suggested that local Societies desirous of undertaking new work might profitably consider—

- (a) Observations of solar radiation.
- (b) Observations of the brightness of the sky at night.

Any Society willing to undertake such work may receive information on the subject by written application to Professor H. H. Turner, F.R.S., the University Observatory, Oxford.

Mr. W. Whitaker, Section C (*Geology*), solicited the aid of local Societies in the work of the Geological Photographs Committee, and expressed the hope that certain Societies would assist the Committee for investigating the Speeton Beds at Knapton.

Mr. W. Croke, Section H (*Anthropology*), stated that he had been directed to lay two suggestions before the meeting:—

First, to draw attention to the work of a Committee formed by Section H with the co-operation of the Anthropological Institute, to collect and register photographs of anthropological interest. He suggested that members of the Corresponding Societies might be asked to co-operate in this work, particularly by the collection of photographs of the best defined types of the peasantry in those parts of the country where they have been least affected by foreign influences. The matter is urgent (as pointed out in a

letter read from Mr. J. L. Myres), because, though these types are still recognisable in favoured and sheltered localities, they are being contaminated rapidly through the agency of modern facilities for intercourse between town and country; and it is only too probable that they will shortly disappear altogether. It is of importance that photographs taken for this purpose in different localities should, as far as possible, be comparable with each other; and the Anthropometric Committee will be glad to furnish detailed instructions and other particulars as to pose, illumination, and the like to any Society or individual who is willing to take up this work. The inquiries should be addressed to the Secretary of the Anthropometric Committee of the British Association.

Secondly, Mr. Crooke invited similar co-operation with a Committee which had been appointed to report upon the best means of registering the megalithic monuments of Great Britain. To this Committee the Conference was invited to appoint a delegate. Photographs of all rude stone monuments and hut circles, particularly those in a stereoscopic form, were much needed.

Professor G. A. Cole (Dublin) suggested that the work of the Anthropometric Committee might be assisted, so far as Ireland was concerned, by application to Mr. John Brown, F.R.S., of the Belfast Natural History Society.

It was resolved to recommend that the Secretary of the Conference (Mr. Rudler) be nominated to serve as Delegate on the Megalithic Monuments Registration Committee.

A letter was read from Mr. E. Heawood, Recorder of Section E (*Geography*), calling the attention of local Societies to the work of the Committee which was appointed last year for investigating 'the Quantity and Composition of Rainfall, and of Lake and River Discharge.' Local observations on the latter subject would be useful, if made systematically, so as to admit of co-ordination with work already done.

On the motion of the Rev. J. O. Bevan, a vote of thanks was passed to the Chairman and Vice-Chairman of the Conference.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1906-1907.

Affiliated Societies.

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 & T. Nisbet, M.A.	330	None	2s. 6d.	Annals, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	J. Langford Ward, Royal Literary and Scientific Institution, Bath	60	5s.	10s.	Proceedings, annually.
Belfast Natural History and Philo- sophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square, R. M. Young, M.R.I.A.	210	None	17. 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	Museum, College Square. W. H. Gallway	410	5s.	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Berwickshire Nat. Club	Rev. J. J. M. L. Aiken, B.D., Manse of Ayrton, Berwickshire	400	None	7s. 6d.	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Birm. & Mid. Inst. Sci. Soc.	Alfred Oresswell, Birm. and Midland Inst., Paradise Street, Birmingham	136	None	10s. 6d.	Records of Meteorological Observations, annually.
Birmingham Natural History and Philo- sophical Society, 1858	Birm. N. H. Phil. Soc.	Avebury House, Newhall Street, Birmingham, W. E. Grove, M.A., and H. G. Perkins	190	None	17. 1s.	Proceedings, occasionally.
Brighton and Hove Natural History and Philosophical Society, 1854	Brighton N. H. Phil. Soc.	J. Colbatch Clark, 9 Marlborough Place, Brighton	160	10s.	10s.	Report, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	J. H. Priestley, B.Sc., University College, Bristol	160	5s.	10s. and 5s.	Proceedings, annually.
British Mycological Society, 1896	British Mycol. Soc.	Carlton Rea, 34 Foregate Street, Worcester	70	None	10s.	Transactions, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, F.I.C., 5 Chapel Street, Peterhead	170	£s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archaeological Society, 1876	Burt. N. H. Arch. Soc.	H. Lloyd Hind, B.Sc., 55 Stantoun Road, Burton-on-Trent	200	None	5s.	Report, annually; Transactions, occasionally.
Canada, Royal Astronomical Society of, 1884	Roy. Astr. Soc. of Canada	Canadian Insurance Building, Toronto. J. R. Collins	200	None	2 dollars	Transactions, annually.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C.	H. E. Forrest, 37 Castle Street, Shrewsbury	179	5s.	5s.	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	William Sheen, M.S., 2 St. Andrew's Crescent, Cardiff	400	None	15s.	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. P. Miln and W. F. J. Shephard	1028	None	5s.	Report and Proceedings, annually.

Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	The Museum, Public Buildings, Penzance, John B. Cornish	98	None	1l. 1s.	Transactions, annually.
Cornwall Royal Polytechnic Society, 1833	Cornwall R. Poly. Soc.	E. W. Newton, Camborne, Cornwall	322	None	10s. upwards	Report, annually.
Croydon Natural History and Scientific Society, 1870	Croydon N. H. Soc.	Public Hall, Croydon, G. W. Moore	180	None	10s.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	Rev. Herbert Pentin, M.A., Milton Abbey Vicarage, Dorset	390	10s.	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1886	Dublin N. F. C.	J. de W. Hinch, National Library of Ireland, Dublin, and F. O. B. Ellison, B.A.	130	5s. Assoc. none	5s. Associate 2s. 6d.	'Irish Naturalist,' monthly; Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gall. N. H. A. Soc.	S. Arnott, Sunnymead, Dumfries	180	None	5s.	Transactions and Proceedings, annually
East Kent Scientific and Natural History Society, 1857	E. Kent S. N. H. Soc.	A. Lander, The Medical Hall, Canterbury	97	None	10s. and 5s.	Transactions, annually.
Eastbourne Natural History Society, 1867	Eastbourne N. H. Soc.	E. J. Bedford, Anderida, Goringe Road, Eastbourne	120	2s. 6d.	7s. 6d.	Transactions, biennially.
Edinburgh Field Naturalists' and Microscopical Society, 1869	Edin. F. N. Mic. Soc.	John Thomson, 141 Comiston Road, Edinburgh	250	5s.	5s.	Transactions, annually.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	India Buildings, Edinburgh. David Glesg.	237	10s. 6d.	12s. 6d.	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	Elgin Lit. Sci. Assoc.	Norris Mackay, W.S., Elgin	196	None	5s.	Transactions, occasionally.
Essex Field Club, 1880	Essex F. C.	William Cole, Springfield, Epping New Road, Buckhurst Hill, Essex	300	None	15s.	'Essex Naturalist,' quarterly; 'Year-book,' annually; 'Special Memoirs,' &c., occasionally.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	Peter Macnair, 207 Bath Street, Glasgow	300	None	10s.	Transactions, biennially.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	Alex. Ross, 409 Great Western Road, Glasgow	293	None	7s. 6d.	Transactions and Proceedings, annually.
Glasgow, Royal Philosophical Society of, 1802	Glasgow R. Phil. Soc.	Prof. Peter Bennett, 207 Bath Street, Glasgow	1,000	1l. 1s.	1l. 1s.	Proceedings, annually.
Halifax Scientific Society, 1874	Halifax S. S.	F. Barker, 11 Hall Street, Halifax	143	None	2s. 6d.	Proceedings, annually.
Hampshire Field Club and Archæological Society, 1885	Hants F. C.	W. Dale, F.S.A., F.G.S., The Lawn, Archer's Road, Southampton	250	None	7s. 6d.	Proceedings, annually.
Haslemere Microscope and Natural History Society, 1888	Haslemere Mic. N. H. Soc.	Rev. G. B. Stallworthy, The Manse, Hindhead, Surrey	452	None	Minimum	Report, annually; Science Papers occasionally.
Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	A. E. Gibbs, F.L.S., St. Albans, and A. Sutton, Watford	160	10s.	2s. 10s.	Transactions, four times a year.
Homesdale Natural History Club, 1857	Holmesdale N. H. C.	G. E. Frisby, 9 Fingates Road, Redhill	94	None	10s. and 5s.	Proceedings, every two or three years.
Hull Geological Society, 1887	Hull Geol. Soc.	J. W. Stather, F.G.S., 16 Louis Street, Hull	77	None	5s.	Transactions, annually.
Hull Scientific and Field Naturalists' Club, 1886	Hull Sci. F. N. C.	T. Sheppard, F.G.S., The Museum, Hull	130	None	5s.	Transactions, annually.
Institution of Mining Engineers, 1889	Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	3,200	None	None	Transactions, monthly.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	E. G. Crichtley, 29 High Street, Inverness	194	None	5s.	Transactions, occasionally.

Affiliated Societies—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
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland.	Dr. W. Lawson, Dr. N. M. Falkiner, and C. H. Oldham, 35 Molesworth Street, Dublin	100	None	1 <i>l.</i>	Journal, annually.
Leeds Geological Association, 1873	Leeds Geol. Assoc.	E. Hawkesworth, Crossgates, Leeds	81	None	5 <i>s.</i>	Transactions, occasionally.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	Norman Treiving, 51 Lofthouse Place, Leeds	77	None	6 <i>s.</i>	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	Corporation Museum, W. A. Evans, 24 Fosse Road South, Leicester	350 Membs. & Associates	None	Members 1 <i>l.</i> ; Associates 10 <i>s.</i> 6 <i>d.</i>	Transactions, half-yearly.
Liverpool Biological Society, 1886	Liverpool Biol. Soc.	J. A. Clubb, M.Sc., Free Public Museum, Liverpool	88	10 <i>s.</i> 6 <i>d.</i> and 2 <i>s.</i> 6 <i>d.</i>	1 <i>l.</i> 1 <i>s.</i> and 10 <i>s.</i> 6 <i>d.</i>	Proceedings and Transactions, annually.
Liverpool Engineering Society, 1875	Liverpool E. Soc.	R. C. F. Annett, 4 Backingham Avenue, Sefton Park, Liverpool	550	None	1 <i>l.</i> 1 <i>s.</i> and 10 <i>s.</i> 6 <i>d.</i>	Transactions and Report, annually.
Liverpool Geographical Society, 1891	Liverpool Geog. Soc.	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Bldgs, Liverpool	640	None	Members 1 <i>l.</i> 1 <i>s.</i> Associates 10 <i>s.</i> 6 <i>d.</i>	Transactions and Report, annually.
Liverpool Geological Society, 1858	Liverpool Geol. Soc.	Royal Institution, W. A. Whitehead, E.Sc.	70	None	1 <i>l.</i> 1 <i>s.</i> and 10 <i>s.</i> 6 <i>d.</i>	Proceedings, annually.
London: City of London College Science Society	Lond. Coll. Sci. Soc.	City of London College, White Street, Moorfields, E.C. H. Norman Gray	80	None	5 <i>s.</i>	Journal, monthly.
London: Quekett Microscopical Club, 1865	Quekett Club	A. Earland, 31 Denmark Street, Watford	402	None	10 <i>s.</i>	Journal, half-yearly.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	Jas. Kewley, M.A., King William College, Castletown, Isle of Man	110	2 <i>s.</i> 6 <i>d.</i>	7 <i>s.</i> 6 <i>d.</i> and 5 <i>s.</i>	Proceedings, quarterly; Transactions, occasionally.
Manchester Geographical Society, 1884	Manch. Geog. Soc.	F. Zimmermann and J. H. Reed, 16 St. Mary's Parsonage, Manchester	600	None	Members 1 <i>l.</i> 1 <i>s.</i> ; Associates 10 <i>s.</i> 6 <i>d.</i>	Journal, quarterly.
Manchester Geological and Mining Society, 1838	Manch. Geol. Min. Soc.	5 John Dalton Street, Manchester.	300	None	2 <i>l.</i> 2 <i>s.</i> , 1 <i>l.</i> 5 <i>s.</i> , and 1 <i>l.</i>	Transactions of Inst. of Mining Engineers, monthly.
Manchester Microscopical Society, 1880	Manch. Mic. Soc.	Sydney A. Smith	213	5 <i>s.</i>	6 <i>s.</i>	Transactions and Report, annually.
Manchester Statistical Society, 1833	Manch. Stat. Soc.	E. C. Stump, Mainsbury, Polefield, Blackley	205	10 <i>s.</i> 6 <i>d.</i>	10 <i>s.</i> 6 <i>d.</i>	Transactions, annually.
Marlborough College Natural History Society, 1864	Marb. Coll. N. H. Soc.	Theodore Gregory, 3 York Street, Manchester	280	1 <i>s.</i> 6 <i>d.</i>	3 <i>s.</i> and 5 <i>s.</i>	Report, annually.
Midland Counties Institution of Engineers, 1871	Mid. Count. Inst.	G. Alfred Lewis, M.A., Albert Street, Derby	420 Membs., Associates & Students	1 <i>l.</i> 1 <i>s.</i>	Members 3 <i>l.</i> 6 <i>s.</i> ; Associates and Students 20 <i>s.</i>	Transactions of Institution of Mining Engineers, monthly.
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	Midland Inst. Eng.	L. T. O'Shea, The University, Sheffield	277	None	5 <i>s.</i>	Transactions of Inst. of Mining Engineers, monthly.
Norfolk and Norwich Naturalists' Society, 1869	Norw. Norw. Nat. Soc.	W. A. Nicholson, St. Helen's Square, Norwich	306	None	1 <i>l.</i> 10 <i>s.</i>	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,350	None	25 <i>s.</i> and 42 <i>s.</i>	Transactions of Inst. of Mining Engineers, monthly.

North Staffordshire Field Club	N. Staff. F. C.	W. Wells Bladen, Stone, Staffs	510	5s.	Report and Transactions, annually. Journal, quarterly.
Northamptonshire Natural History Society and Field Club, 1876	Northants N. H. Soc.	H. N. Dixon, M.A., 23 East Park Parade, Northampton	210	10s.	Transactions, annually.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829	Northumb. N. H. Soc.	Hancock Museum, Newcastle-upon-Tyne. N. H. Martin, F.L.S., and C. E. Robson	430	21s.	Report and Transactions, annually.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Prof. J. W. Carr, M.A., University College, Nottingham	184	5s.	Report, annually; Meteorological Obs., occasionally.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	630	7s. 6d.	Transactions and Proceedings, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	390	5s. 6d.	Transactions, biennially.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, D.Sc., 105 Freehold Street, Rochdale	247	6s.	'Rochester Naturalist,' quarterly.
Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Linden House, Rochester	186	5s.	Proceedings, annually.
Somersetshire Archeological and Natural History Society, 1849	Som'setsh. A. N. H. Soc.	The Castle, Tamton. Rev. F. W. Weaver, Rev. E. H. Bates, and C. Tite	661	10s. 6d.	Transactions, occasionally.
South African Philosophical Society, 1877	S. African Phil. Soc.	G. M. Clark, South African Museum, Cape Town	207	2l.	'South-Eastern Naturalist,' annually.
South-Eastern Union of Scientific Societies, 1896	S.-E. Union	Rev. R. Ashington Bullen, B.A., Hursptierpoint	45 Societies	Minimum 5s.	Proceedings, annually.
Southport Literary and Philological Society	Southport Lit. & Phil. Soc.	Arthur Quayle, 409 Lord Street, Southport	145	7s. 6d.	Transactions of Institution of Mining Engineers, monthly.
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	S. Staff. Inst. Eng.	Alexander Smith, M.Inst.E.C., 3 Newhall Street, Birmingham	192	31s. 6d. and 21s. 10s. 6d.	Transactions, occasionally.
Tyneside Geographical Society, 1887	Tyneside Geog. Soc.	Geographical Institute, St. Mary's Place, Newcastle-upon-Tyne. Herbert Shaw, B.A., F.R.G.S.	1,000	10s.	Proceedings, annually.
Vale of Derwent Naturalists' Field Club, 1887	Vale of Derwent Nat. F. C.	W. Johnson, Byer Moor, Burnopfield, Co. Durham	102	2s. 6d.	Transactions, occasionally.
Warwickshire Naturalists' and Archeologists' Field Club, 1884	Warw. N. A. F. C.	Museum, Warwick. O. West, Cross Cheaping, Coventry	75	5s.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C.	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	260	10s.	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, M.A., F.G.S., Hopton, Mirfield	204	13s.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	The Museum, Hull. T. Sheppard, F.G.S.	406 and 2,700 Associates	10s. 6d.	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc.	Museum, York. Dr. Tempest Anderson and C. E. Elmhurst.	480	2l.	Report, annually.

Associated Societies.

Full Title and Date of Foundation	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Bakewell Naturalists' Club, 1896	W. Storrs Fox, M.A., F.Z.S., St. Anselm's, Bakenwell	55	None	5s. and 2s. 6d.	—
Balham and District Antiquarian and Natural History Society, 1897	A. L. Barron, Clophill, Wallington, Surrey	50	None	5s.	Papers occasionally.
Barrow Naturalists' Field Club and Literary and Scientific Association, 1876	Cambridge Hall, Strand, Barrow. E. W. Plant	339	None	5s. and 2s. 6d.	Report and Proceedings, &c., annually.
Battersca Field Club, 1894	Public Library, Lavender Hill, Battersca, S.W. Everard J. Davies	53	None	3s. 6d.	—
Bradford Natural History and Microscopical Society, 1875	Fred. Jowett, Wilton Street, Bradford	74	1s.	4s.	—
Catford and District Natural History Society, 1897	W. H. Griffin, 4 Rutland Gate, Catford, S.E. Percy Moring, 23 Randolph Gardens, Dover	80 72	1s. None	3s. 6s.	— Reports, annually; leaflets, irregularly.
Dunfermline Naturalists' Society, 1902	Robert Somerville, B.Sc., 82 James Street, Dunfermline	218	None	5s.	—
Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, 133 The Grove, Ealing, W. The Museum, Grimsby. Calcib Nightingale	124 75	None None	10s. and 2s. 6d. 4s.	Report and Transactions, annually.
Grimsby and District Antiquarian and Naturalists' Society, 1896	C. O. Bartrum, B.Sc., 3 Holford Road, Hampstead, N.W. Corporation Museum, Brassey Institute, Hastings. W. Ruskin Butterfield	314	None	Minimum 5s.	Report and Proceedings, annually.
Hampstead Scientific Society, 1899	Charles B. White, 19 Salisbury Road, Ipswich	280	1s.	2s. 6d.	—
Hastings and St. Leonards Natural History Society, 1893	Royal Institution, Liverpool. H. R. Sweeting, M.A. J. W. Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S.E.	140 110	None None	1s. 5s.	— Report and Proceedings, annually.
Ipswich and District Field Club, 1903	The London Institution, Finsbury Circus, E.C. Edward Harris	150	None	5s.	—
Lancashire and Cheshire Entomological Society, 1877	R. W. Robbins, 179 Hall End Road, Walthamstow	65	10s. 6d.	10s. 6d.	Report, annually
Lewisham Antiquarian Society, 1895	Hibernia Chambers, London Bridge, S.E. Stanley Edwards	55	2s. 6d.	5s.	—
Liverpool Microscopical Society, 1866	Newcastle-upon-Tyne. Alfred Holmes and Frederick Emley	76	2s. 6d.	7s. 6d.	Transactions, annually.
Liverpool Science Students' Association, 1881	Public Buildings, Penzance. J. B. Cornish	106	2s. 6d.	5s. and 2s. 6d.	—
London: City of London Entomological and Natural History Society, 1858	Lecture Hall, 119A Fishergate, Preston. W. Hy. Heathcote	180	2s. 6d.	7s. 6d.	Proceedings, annually.
London: North London Natural History Society, 1892	Philosophical Institution, 4 Queen Street, Edinburgh. Dr. W. G. Robertson	2,800	None	14. 1s.	—
London: South London Entomological and Natural History Society, 1872	W. T. Barnett, 52 Tabbot Street, Southport	50	None	10s. 6d.	—
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1783	P. F. S. Amery, Druid, Ashburton, Devon	598	None	5s.	Papers, occasionally.
Penzance Natural History and Antiquarian Society, 1839	Alex. Somerville, The Museum, Torquay	60	None	10s. 6d.	Proceedings, annually.
Preston Scientific Society, 1893	L. R. Hutchinson, 28 Princes Street, Tunbridge Wells	241 120 209	None None 10s. 6d.	5s. 2s. 6d. 14. 1s.	— — —
Scottish Microscopical Society, 1888	R. R. Hutchinson, 28 Princes Street, Tunbridge Wells	157	None	10s. 6d., 5s. and 3s. 6d.	Report, annually.
Southport Society of Natural Science, 1890	Alf. J. Jolley, 16 Arpley Street, Warrington	53	None	2s.	—
Teign Naturalists' Field Club, 1858	E. H. Jackson, 100 High Street, Watford	63	None	10s. and 5s.	—
Torquay Natural History Society, 1844					
Tunbridge Wells Natural History and Philosophical Society, 1884					
Warrington Field Club, 1884					
Watford Camera Club, 1902					

Catalogue of the more important Papers, especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1906.

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

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- ANDSON, Rev. WILLIAM. The Meteorology of 1900. 'Trans. Dum. Gall. N. H. A. Soc.' xvii. 33-38. 1905.
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- BECKER, Prof. LUDWIG. Progress of Astronomy in the Nineteenth Century. 'Proc. Glasgow R. Phil. Soc.' xxxvi. 136-183. 1905.
- BLADEN, W. WELLS. Report of the Meteorological Section. 'Report N. Staff. F. C.' xi. 138-144. 1906.
- BOLHAM, GEORGE (extracted by). Meteorological Observations at Cheswick for 1900, 1901, 1902, and 1903, by the late Major-General Sir William Crossman, K.C.M.G., and continued by his Son, L. Morley Crossman, Esq. 'History Berwicksh. Nat. Club,' xix. 91-94. 1905.
- BROWN, M. WALTON. Barometer, Thermometer, &c., Readings for the Year 1903. 'Trans. Inst. Min. Eng.' xxvii. 743-752. 1906.
- CAMPBELL-BAYARD, F. Meteorological Report for 1904. 'Trans. Croydon N. H. Sci. Soc. 1904-1905,' 115-122, and Appendices, 51 pp. 1905.
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- CHANT, Dr. C. A. Astronomical and Astrophysical Progress in 1905. (Presidential Address.) 'Trans. Roy. Astr. Soc. of Canada for 1905,' 13-26. 1906.
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- LOUDON, W. J. A Lunar Tide on Lake Huron. 'Trans. Roy. Astr. Soc. of Canada for 1905,' 131-140. 1906.
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Magnetic Observations at Falmouth Observatory.—Report of the Committee, consisting of Sir W. H. PREECE (Chairman), Dr. R. T. GLAZEBROOK (Secretary), Professor W. G. ADAMS, Dr. CHREE, Captain CREAK, Mr. W. L. FOX, Sir A. W. RÜCKER, and Professor A. SCHUSTER.

THE Grant voted by the Association last year has been expended in carrying on the magnetic observations at Falmouth Observatory. The results of the observations have been published in the Annual Report of

the National Physical Laboratory, as well as in the Annual Report of the Royal Cornwall Polytechnic Society. They appear as satisfactory as in previous years.

The instruments were inspected in September 1905 by Mr. T. W. Baker, who took some absolute observations showing a satisfactory accordance with those taken by Mr. Kitto.

Dr. Chree has published 'A comparison of the results from the Falmouth Declination and Horizontal Force Magnetographs on quiet days in years of Sun-Spot maximum and minimum' in the 'Transactions' of the Cambridge Philosophical Society, vol. xx. 1906; the results are closely analogous to, but in some respects more complete than, those deduced from his earlier papers dealing with the Kew curves.

The Committee regret to learn that the new Observatory at Eskdale Muir continues to make somewhat slow progress and will not be ready until some time in 1907. In view of the importance of maintaining continuity of the magnetic records, they ask for reappointment with a grant of 50*l*.

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord McLAREN, Professor CRUM BROWN (Secretary), Sir JOHN MURRAY, Dr. ALEXANDER BUCHAN, and Mr. R. T. OMOND. (Drawn up by Dr. BUCHAN.)

THE Committee, which was in former years appointed for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations at the two Ben Nevis Observatories, has, since the closing of these observatories in October 1904, devoted its attention to the publication and discussion of the observations made at these observatories.

The Hourly Observations from the opening of the Ben Nevis Observatories in 1883 to the end of 1897 have now been published by the Royal Society of Edinburgh, assisted by a grant of 500*l*. from the Publications Fund of the Royal Society of London. They form Volumes 34, 42, and 43 of the 'Transactions of the Royal Society of Edinburgh.' The last of these volumes was issued during the current year. These volumes contain, in addition to the hourly observations, a *résumé* of the hourly values for each individual year; and the last published volume, being Vol. 43 of 'Transactions of the Royal Society of Edinburgh,' gives, in addition, the hourly values of the observations made from the opening of the observatories, in 1883, to October 1904. In this volume papers are also given in which the observations are discussed in relation to weather and to atmospheric physics.

In the meantime arrangements are made for the continuation of these large discussions, which it is contemplated will occupy about three years.

Seismological Investigations.—Eleventh Report of the Committee, consisting of Professor J. W. JUDD (Chairman), Mr. J. MILNE (Secretary), Lord KELVIN, Dr. T. G. BONNEY, Mr. C. VERNON BOYS, Sir GEORGE DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Professor J. A. EWING, Dr. R. T. GLAZEBROOK, Mr. M. H. GRAY, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Mr. W. E. PLUMMER, Professor J. H. POYNTING, Mr. CLEMENT REID, Mr. NELSON RICHARDSON, and Professor H. H. TURNER. (Drawn up by the Secretary.)

[PLATE I.]

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I. *General Notes on Stations and Registers.*

THE registers issued during the past year are Circulars Nos. 12 and 13. They refer to Shide, Kew, Bidston, Edinburgh, Paisley, Toronto, Victoria (B.C.), San Fernando (Spain), Ponta Delgada (Azores), Cape of Good Hope, Alipore, Bombay, Kodaikānal, Batavia, Perth, Trinidad, Christchurch, Cairo, Irkutsk, Baltimore, Beirūt, Honolulu, Cheltenham (Md. U.S.A.), and Vieques (Porto Rico).

From the United States Coast and Geodetic Survey the Secretary has received records from the Milne pendulum established in Honolulu, together with records from Bosch-Omori pendulums installed at Vieques (Porto Rico), Cheltenham Md. U.S.A., and Sitka.

These registers appear in Circular No. 13.

Records have not yet been received from Melbourne, Sydney, and Arequipa; while registers from Tokyo, Wellington, Philadelphia and Mexico should be brought up to date. The Seismological Committee of the British Association would be greatly indebted to the Directors of Observatories at these places if they would kindly forward copies of their observations.

During the last year Milne pendulums have been installed at Old Frensham Hall, Haslemere, Surrey, at the University in Malta, and at the National Observatory in Paris.

All instruments record photographically on cylinders moving at the rate of 25 c.m. per hour. The two first instruments are single component, while the latter gives a two-component record. The instrument at Haslemere was established by the late Hon. Charles Ellis, who, in addition to giving this assistance to observational seismology in this country, forwarded to the Secretary a cheque for 200*l.*, to be used as he considered best to assist seismological research. Your Committee suggest that it be employed towards the general expenses at Shide station,

particularly in connection with an increase in office accommodation. Mr. Richard Cooke, The Croft, Detling, Maidstone, has kindly sent 17. 1s. as an annual subscription for the support of seismological research.

II. *The Situation of Stations.*

Continued from 'British Association Report,' 1905, p. 84.

Achalaki.

The town lies on a plateau. Beneath the town we find two lava streams, the lower one trachytic with a columnar structure, here dense and there porous. Above this there is a dolomite schist, in parts solid and in others porous. These are separated from one another by schistose sandstone of Miocene age with slate and layers of coal.

Batoum.

The town lies in the Kachaber low ground, which is formed of the deposit of the river Tschoroch. A vertical section through the low ground shows the following horizontal strata in downward succession:—

Humus	0.355 metre
Hard clay	2.84 „
Clayey sand mixed with pebbles	1.42 „
Sand	1.065 „

The heights surrounding the town consist of different sorts of andesite and tufa.

Borshom.

The little town of Borshom lies in the valley of the river Kura, and its tributary rivers Borshomka and Tschornaja Retchka.

The tectonic formation which is shown in the neighbourhood of Borshom may be summarised as follows: Steep sloping strata of the Eocene period intermingled with andesite strata form anticlinal and synclinal folds. The protruding ends of strata consist of andesite lava in layers and streams.

The sedimentary formation is represented by marl and argillaceous sandstone. The marl possesses the peculiarity of being broken into small pieces; the sandstone is traversed by a system of perpendicular clefts inclining to a cubical cleavage.

The region on the right side of the Kura forms a plateau which is an anticlinal; the middle of the plateau coincides with the ridge of the anticlinal, and strikes N.W.—S.E.

Upon the left side of the Kura, where the seismic station is situated, there is a deposit of sandstone and marl in layers with a uniform dip of 15° N.E.

Schemacha.

The town lies partly on the slope of the valley of the river Dsoga-Lawa and partly in the river valley itself. No account of the structure of the district has been published. Many varieties of sedimentary rocks belonging to the Tertiary period are to be found.

In the town towards the south, Muschelkalk schist supported by clay slate dips N.W.

On the southern face of the height which rises above the town one finds the same limestones exposed, which in their higher part dip S.E., but in the lower part W.S.W.

In a deep ditch not far from the prison we find laminated plastic clays which support intermediate layers of marl, sandy clay, and lime sandstone.

To the south of the town, not far from the village Bojat, one finds the following strata exposed in this order downwards:—

- (a) Yellow and brown coloured sandy clay.
- (b) Various layers of insignificant thickness of yellow and white clays.
- (c) Shell limestone (Muschelkalk) with *Cardium (sic)* and *Maetra*.
- (d) White and yellow porous sandstone with shells.

Derbent.

The town lies on the lower shore of the Caspian Sea.

The nearest point of interest from the town is the mountain Dschalgan, whose steep brows approach the town from the south-west. To the southerly side of the mountain we find a synclinal fault which stretches N.W.—S.E., and dips south-east. In the direction of the town the tectonic structure becomes tolerably complicated, and the connection of the Dschalgan synclinal with the flat dome-shaped anticlinal which comes to sight on the north side of the town is not yet explained. Tertiary deposits as well as the Quaternary Loess formation are also found. The latter deposit stretches from the sea-shore at Derbent to a height of 100 fathoms up the brow of the Dschalgan.

In the sea-cliffs, not far from the railway station, shell lime rocks come to view.

The remainder of the Dschalgan heights are formed of limestone, sandstone and clay. Along the south-east brows of the Dschalgan, not far from the fortress, one finds the following strata cropping up in ascending order:—

1. Grey and coffee-brown coloured sandy clay.
2. 3–2 inches of clay strata with ferruginous grains.
3. Layers of white sandy clays.
4. Grey shell limestone (holding Mactra), 17–15 fathoms thick.
5. Dividing layers of marl clay with broken pieces of Mactra shells, 3 inches.
6. Grey Mactra shell limestone, 14–15 fathoms.
7. Dividing layer clay marl, 14 inches.
8. Yellowish solid limestone with few large shells of Mactra, such as Vitaliana, d'Orb.

Tiflis.

The town lies on the slopes of the valley of the river Kura.

With the exception of a few places, where primitive rock comes to view, the surface formation of the Tiflis valley is composed of clayey sandstone and loam deposits, whose thickness amounts in places to 80 feet and more. This is covered with horizontal strata of alluvium.

The heights in the environs of the town consist of the above rocks, together with sedimentary and volcanic rock débris, which are cemented together by a clayey medium.

In an exposure on the right bank of the Kura, in the immediate neighbourhood of the seismic station, one finds more or less thinly laminated clay sandstone of a grey colour; the same stratification is to be seen in the bottom of a deep trench which surrounds the station. The foundations of the station, as well as all seismographs, are directly set on the original rock.

III. *The Origins of Large Earthquakes in 1905.*

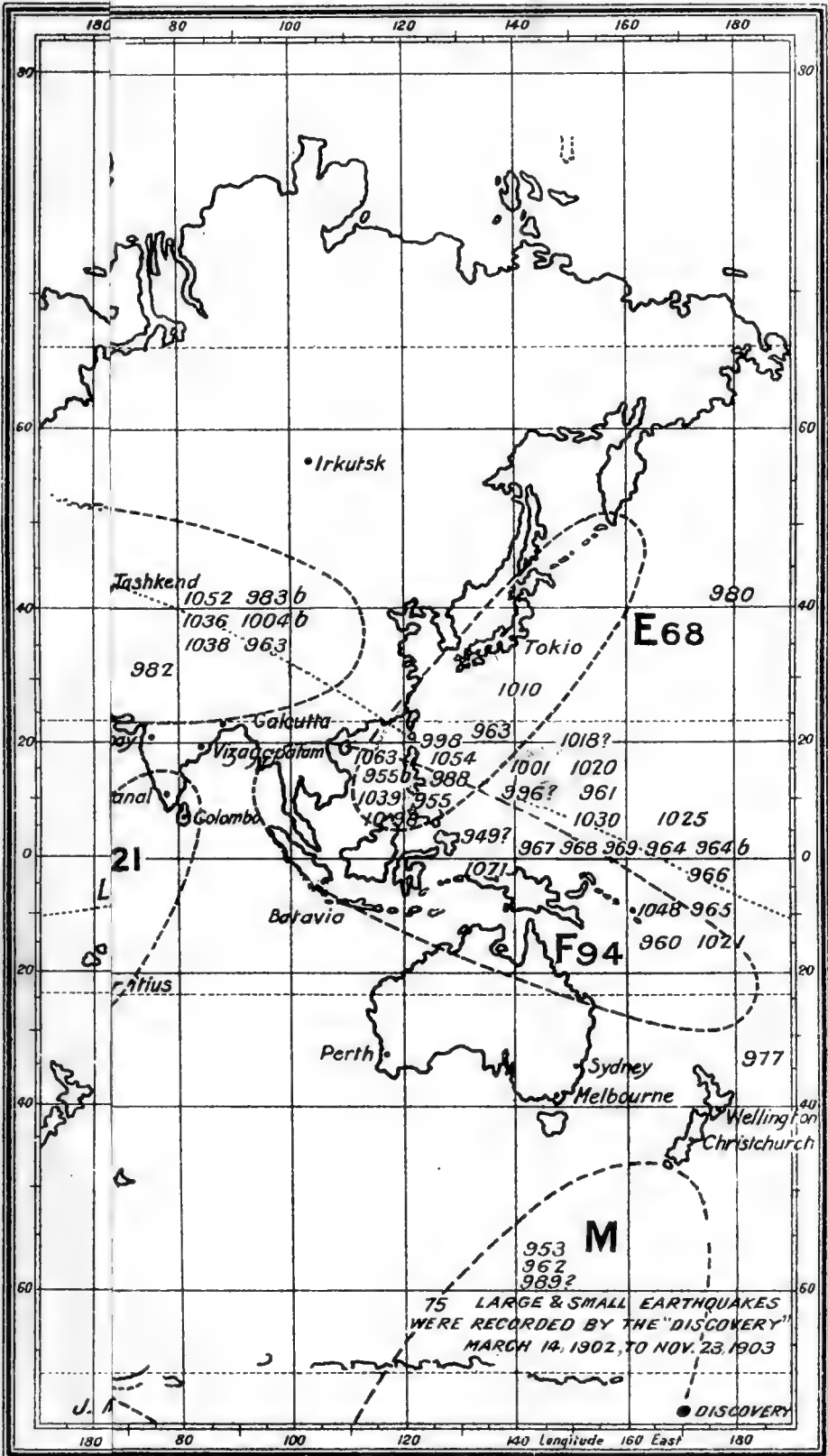
In registers from different stations in 1905, as in other years, the number of entries vary within wide limits. In the list for Shide there are 159 entries, but 47 of these refer to extremely minute displacements the nature of which is uncertain. Disturbances which are undoubtedly of seismic origin are therefore 112. Out of these 56 were distinctly megaseismic. On the accompanying map (Plate I.) the origins of 57 widespread movements are indicated. This number happens to be the annual average for the years 1899 to 1905 inclusive.

A glance at the map shows, with but few exceptions, that these earthquakes are confined to a circle passing from Central America through the Azores, the Alpine, Balkan and Himalayan ranges, into the East Indian Archipelago.

The quiescence of districts not lying on this band is very marked.

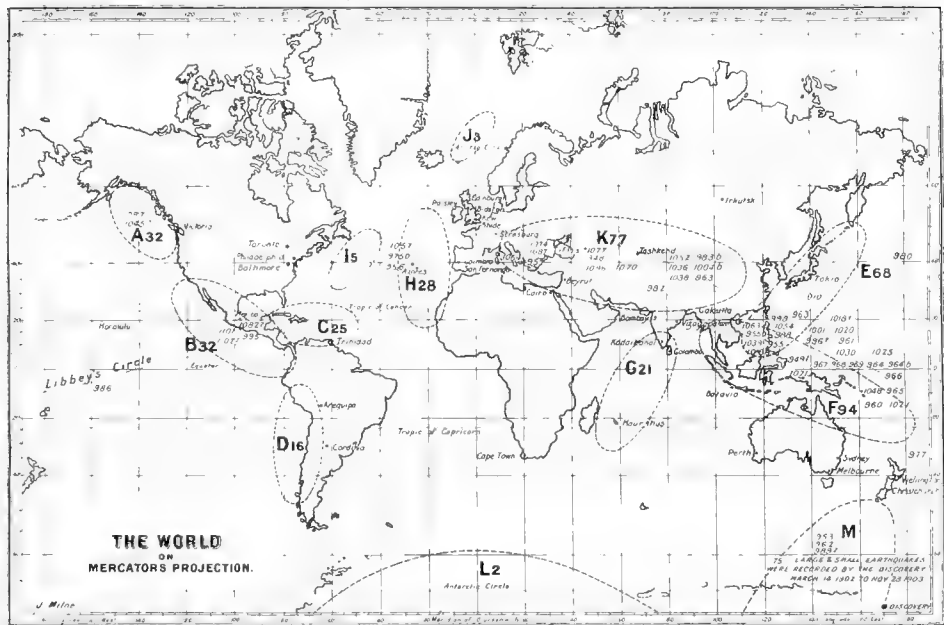
Destructive earthquakes occurred on April 4 in N.W. India, and on September 8 in Calabria. Whether the latter was in any way connected with the relief of volcanic stress which commenced in May 1905 and

and the number of earthquakes which since 1899 have originated



Origins for 1905 are indicated by their B. A. Slide Register no. after
 from these is referred to large contours.
 Observatory stations are named

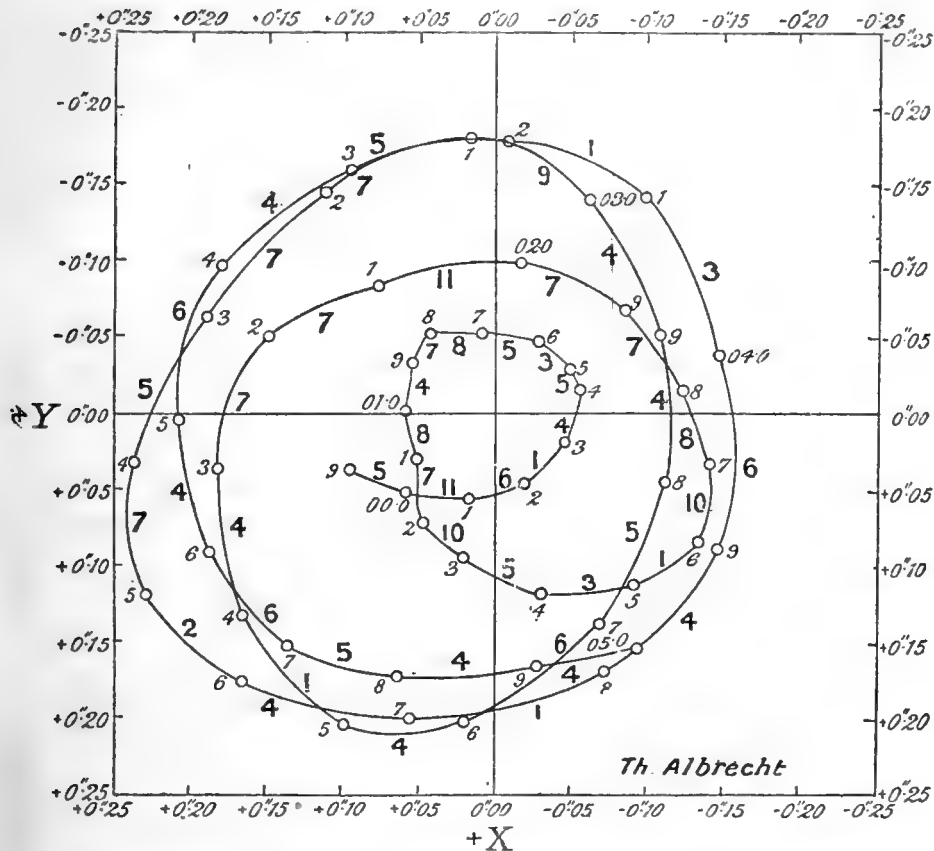
Earthquake districts are indicated A, B, C, &c., and the number of earthquakes which since 1899 have originated



Illustrating the Report on Seismological Investigations

culminated in the violent eruptions at Vesuvius in April 1906 is a matter of conjecture. The largest earthquakes, eclipsing either of these, or the one of April 18, 1906, which devastated Central California, were numbers 1036 and 1052. They originated in Central Asia, one on July 9, and

FIG. 1.



the other on July 23, 1905. As accounts of destruction do not appear to have reached Europe, it may be assumed that the epifocal areas were only sparsely populated. The latter disturbance was felt in Tomsk, Kiachta, and other places.

IV. Large Earthquakes in relation to Time and Space.

Megaseismic motion has been automatically recorded since 1884.¹ Maps showing the origins of world-shaking earthquakes have been published in 'British Association Reports' since 1899. The last refers to the earthquakes of 1905, and is contained in this report. When, therefore, we are considering the time-relationship between earthquakes originating in different localities, the records at our disposal only extend over seven years. The material is admittedly as yet far too meagre to give satisfactory results, but, nevertheless, it is interesting to note the direction in which it points.

¹ *Seis. Soc. Trans.*, vol. x., p. 6.

In the following table megaseismic origins are classified under three heads :—

I. Refers to the East Pacific Coast north of the Equator, including the parallel Antillean Fold, shown on the map as District C.

II. Refers to the Western and South-Western portions of the North Pacific.

III. Refers to the folds extending from the Balkans to the Himalayas.

The first two divisions relate to earthquakes with a sub-oceanic origin, whilst the third relates to those which have originated in a continental area.

I.

Districts	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
A, B & C	1899	3	6	1 or 2	1	0	0 or 1	3	0 or 1	7 or 10	0	2	1	24
"	1900	5	1	0	2	1	3	2	0	2	2	3	2	23
"	1901	3	1	2	1	2	0	0	0	0	4 or 5	0	3 or 4	16
"	1902	4 or 5	2	3	1	0	0	0	0	1	0	1	1	13
"	1903	3 or 4	2	2	2	0	1	0	1	1	0	0	0	12
"	1904	0	0	0	0	0	0	0	0	0	0	0	0	0
"	1905	0	0	0	0	1	0	1	0	0	1	0	2 or 3	5
Total Minimum		18	12	8	7	4	4	6	1	11	7	6	9	93

II.

E & F	1899	1	0	2	0	1	1	6	3	1	3 or 4	5	1	24
"	1900	3	0	2 or 3	1	1	1	1	5	3	2	2	0	21
"	1901	2	1	1	0	2	1	0	4 or 5	2 or 3	0	1	1	15
"	1902	6	2 or 3	3	0	2	1	1	2	2	0	3	0	22
"	1903	3	5	0	0	2	1	0	2	0	2	2	3	20
"	1904	2	0	0	1	2	4 or 6	3	2	1	2	2	1	20
"	1905	2	6	3 or 5	5	4	5	3	1	3	0	0	0	32
Total minimum		19	14	11	7	14	14	14	19	12	9	15	6	154

III.

K	1899	0	0	2	0	0	0	0	0	0	1	0	1	4
"	1900	0	0	1	0	0	0	0	0	0	0	0	0	1
"	1901	0	0	1	1	0	1	0	1	1	1	2	0	8
"	1902	0	1	2	0	2	1	2	6	2	1	1	2	20
"	1903	0	4	3	2	1	1	1	2	1	0	0	1	16
"	1904	0	0	1 or 2	2	0	0	0	0	0	0	0	0	3
"	1905	2	0	0	1	1	1	3	0	2	1	1	0	12
Total minimum		2	5	10	6	4	4	6	9	6	4	4	4	64
Total for all districts		39	31	34	24	22	24	26	31	29	20	25	19	324

If we take the months April to September as summer months, and October to March as winter months, we find the following numerical seasonal distribution :—

	Summer	Winter
N.E. Pacific	33	60
W. and S.W. Pacific	80	74
Balkan and Himalayan	35	29
Total	148	163

These epitomised results indicate that on the west side of the Pacific seismic frequency is greatest in summer, whilst on the eastern side it is greatest in winter.

Assuming the alternation in frequency in these two districts to be real, an explanation for the same may possibly be found in the seasonal alternation in the flow of ocean currents, the measured oscillations of sea-level, and the changes in the direction of barometric gradients—phenomena which are inter-related.

In summer-time off the coast of Japan the Kuro Siwo or Black Stream runs further northward in that season than in winter; while Dr. Omori tells us that although barometric pressure may be low at this time, this decrement in load is more than compensated for by the increased height in oceanic level.

For the third region the summer frequency for the land area is nearly identical with that of the West Pacific.

V. *Relationship of Large Earthquakes to each other and to Volcanic Eruptions.*

In any two districts, or in the same district, no apparent time-relationship between the occurrence of successive megaseisms has yet been formulated. If, however, we consider groups of large earthquakes which have occurred in a particular district, we may find a yearly decrease in their numbers, as in district A, while in districts like F and K there may be an increase. The time-relationship between after-shocks is well known. A striking illustration of the connections between a large earthquake and small shocks in a neighbouring district, together with displays of volcanic activity, occurred on January 31, 1906. On that date the coast of Colombia was inundated, islands sank at the mouth of the Esmeralda River, a cable was broken, and the volcano Cumbal erupted. These changes on the flanks of the Cordilleras were followed by disturbances in the Antilles.

Many small earthquakes occurred, and on February 16 several of them were sufficiently severe to damage masonry. Mount Pelée and La Soufrière showed signs of increased activity, and eight, if not nine, cable interruptions were recorded.

Here we have another illustration of the remarkable relationship which exists between the hypogenic activities of these parallel folds, a disturbance in one being accompanied or followed by a response in the other.¹

VI. *Earthquakes and Changes in Latitude.*

The following table is a continuation of one published in the 'British Association Report,' 1903, pp. 78-80:—

Periods	1900	1901	1902	1903	1904
0-1, Jan. 1 to Feb. 5	11	8	11	{ 9	3
1-2, Feb. 5 to March 14.	6	{ 7	{ 7	{ 7	1
2-3, March 14 to April 19	1	{ 10	{ 7	7	5
3-4, April 19 to May 26.	{ 4	5	4	5	{ 4
4-5, May 26 to July 1	{ 5	3	{ 1	{ 7	{ 6
5-6, July 1 to Aug. 7	3	{ 1	{ 4	{ 2	4
6-7, Aug. 7 to Sept. 12	5	{ 10	6	4	{ 6
7-8, Sept. 12 to Oct. 19	{ 8	8	5	1	{ 5
8-9, Oct. 19 to Nov. 24	{ 7	7	4	{ 4	4
9-10, Nov. 24 to Dec. 31	4	7	4	{ 6	4

¹ See *Brit. Assoc. Rep.*, 1902, p. 73.

The numerals indicate the number of large earthquakes which occurred in successive periods of 36·5 days.

Two periods connected by brackets indicate times when the change in direction of pole-movement, as shown on Albrecht's figure, was comparatively rapid (see fig. 1).

If we compare the number of earthquakes which occurred in these selected periods with the total number of earthquakes which were recorded in equal intervals of time before and after the deflection periods we obtain the following results:—

	Com- parable Totals
Earthquakes before deflection: 7 8 12 8 18 — 8 12 5 6 —	= 60
„ during „ 9 15 17 11 14 5 16 9 10 10 11	= 87
„ after „ 8 12 8 15 — 11 12 5 4 — 8	= 64

Omitting the four cases where figures for comparison are not complete, out of seven deflections there are six instances where the greater number of earthquakes have taken place during deflection periods.

If this result be added to that for the years 1892 to 1899¹ we see that out of twenty-three deflection periods there are eighteen instances where the greater number of earthquakes have been recorded for the deflection period. The totals for before, during, and after comparable deflection periods are respectively 167, 287, and 217, or as 1 : 1·72 : 1·29.

A closer determination of the possible relationship between pole-deflections and earthquake-frequency is obtained if the deflections between successive periods are expressed in angular measure. Such measurements have been made for each of the ten periods in the years 1899 to 1904. Opposite to each measurement figures give the number of earthquakes which occurred during the seventy-three days to which a measurement refers.

These have been divided into two groups. The first group embraces observations made in the years 1892 to 1899. During this interval the pole-path shows many irregularities.²

The second group refers to the periods between 1901(-6) and 1905(-0). During this interval the pole-path was comparatively regular (see fig. 1).

Group I.

Deflections	No. of Deflections	No. of Earthquakes	Average No. of Earthquakes	Group Averages
0 to 5	1	18	18	—
5 „ 10	7	153	22	—
10 „ 15	8	32	4	} 6·9
15 „ 20	4	13	3	
20 „ 25	13	128	9	} 14·5
25 „ 30	10	185	18	
30 „ 35	9	115	13	
35 „ 40	11	137	13	} 17·7
40 „ 45	5	67	13	
45 „ 50	6	115	19	
50 „ 55	6	120	20	—
55 „ 60	2	42	21	—
60 „ 75	5	122	24	—

¹ See *Brit. Assoc. Rep.*, 1893, p. 80.

² *Ibid.*, 1903, p. 80, fig. 2.

If we omit the first two entries in this table it appears that the average number of earthquakes in any period is approximately directly proportional to angular deflections of the pole-path during that period.

A similar result is shown in the three group averages which are given :—

Group II.

Deflections	No. of Deflections	No. of Earthquakes	Average No. of Earthquakes	Deflections	No. of Deflections	No. of Earthquakes	Average No. of Earthquakes
0° to 10°	1	8	8	30° to 35°	8	89	11
10° „ 15°	2	33	16	35° „ 40°	5	62	12
15° „ 20°	3	39	16	40° „ 45°	5	43	8
20° „ 25°	2	18	9	45° „ 52°	2	21	10
25° „ 30°	13	134	10				

In this instance, where the path of the pole relatively to its mean position has been fairly uniform, earthquake-frequency does not appear to have been influenced.

VII. *On the Change of Level on two sides of a Valley.*

It has been found that under certain but frequently recurring conditions the two opposite sides of a valley move in opposite directions at the same time. On bright fine days the inclinations of the sides of a valley decrease. At night they increase. A valley may therefore be supposed to open and close. These conclusions, which do not necessarily apply to all valleys, are based on observations taken in two very different localities. The first were made in Tokyo, Japan, by means of horizontal pendulums giving continuous photographic records, installed on the two sides of a valley cut in alluvium.¹

The second series were made on the two sides of a valley cut in chalk at Shide, near Newport, in the Isle of Wight. On the western side of the valley the instrument employed was an astronomical level reading to 1''·0 of arc. On the eastern side change of level was continuously recorded by a horizontal pendulum easily reading to 0''·5 of arc. Both were well founded and well protected from direct effects of solar radiation. When the instruments were side by side they gave similar and practically identical results.

The level, which was in charge of Mr. H. G. Morgan Hobbs, resident at Sunnyside, was read three times a day from July 26 to August 27, 1905. The difference between successive readings usually varied between 0''·5 and 3''·0, and with but few exceptions these readings indicated changes in level in opposite directions. During wet weather the diurnal movement was eclipsed by a rapid movement in a direction which corresponded with a closing of the valley. This sometimes amounted to 18''·0.

These diurnal changes in the vertical have been found in chambers excavated in rock, and at other installations when the daily change in temperature has not exceeded 2° F. They have been recorded in the New Red Sandstone at a depth of 19 feet. From these and other observations it is clear that they cannot be attributed to any warping effect in the instrument or change in temperature at the base of a pier on which an

¹ See *Brit. Assoc. Rep.*, 1895, p. 132.

instrument has been installed. They may, however, be due to the general warping of a district under the influence of solar radiation, or to the differential effects of loading and unloading of portions of the same. During the day the sides of a valley covered with vegetation lose load by evaporation and transpiration, and therefore underground drainage, tending to carry a water load to the bottom of a valley, is reduced. At night, with the cessation of these processes, the load at the bottom of a valley is increased. At that time streams and certain wells carry their greatest quantity of water. It is therefore at night that a valley may be expected to sag downwards, a suggestion that finds support in the observation that during wet weather, when we see streams in flood, the sides of the bounding valley approach each other in a marked manner.

The conclusion is that as the world turns before the sun its surface is measurably smoothed, whilst at night the frecklings on its face are measurably increased.

VIII. *Antarctic Earthquakes.*

From March 14, 1902, to December 31, 1903, a horizontal pendulum of the British Association type was installed in Victoria Land, about fifteen miles distant from Mounts Erebus and Terror. The instrument was in charge of Mr. Louis Bernacchi, who was attached to the s.s. 'Discovery.' Although observations were made under exceptional difficulties, Mr. Bernacchi brought back about 3,000 feet of photographic film. This was examined by your Secretary, Mr. Shinobu Hirota, and Mr. Howard Burgess of Newport. 'Preliminary Notes' on this analysis are to be found in the 'Proceedings of the Royal Society,' vol. A76, 1905, pp. 284-295. The more important results are as follows:—

1. Out of 136 records of earthquakes seventy-three refer to disturbances which originated in a sub-oceanic region between New Zealand and Victoria Land. In the British Association maps of Seismic Distribution this new district is indicated by the letter M. The greatest frequency was in the months April, May and June.

2. Certain earthquakes from district M have been recorded to the south-east by the 'Discovery,' and along a band about 20° in width towards the north-west as far as Britain. This phenomenon of recordable motion being propagated in one direction only round the world is now known to be true for earthquakes originating in other districts.

3. An earthquake may be recorded at stations near its origin and its antipodes, but not at intermediate stations.

4. As an earthquake radiates, the phase of motion which travels the greatest distance is that of the largest waves or P_3 .

5. The average arcual velocity for P_3 is approximately 3 Km per second, with a possible acceleration in the quadrantal region of its path, where it may reach 4 Km per second.

6. Other results refer to slow changes in the vertical, diurnal waves, tremors and pulsations.

IX. *Note on the Determination of the Time of Origin of Earthquakes.*

By R. D. OLDHAM.

One of the greatest desiderata in the study of the nature and propagation of earthquake waves is an exact determination of the time of origin of the earthquake. Few are the instances where a great

earthquake occurs in countries sufficiently civilised to allow of an accurate determination by direct observation, more frequently we have one or two instrumental records at distances of a hundred to a thousand miles from the origin, and the results obtained from the study of individual earthquakes have so far been too discordant to enable these to be used with certainty. Recently Professor Imamura has published a memoir 'On the Transit Velocity of the Earthquake Motion originating at a Near Distance,'¹ which should be of assistance, but, owing to the mode of discussion adopted, his results are not directly applicable for the purpose in hand. As, however, all the data are published in detail, I have been able to plot them on squared paper and obtain two time-curves from which the intervals tabulated below were measured.

Table showing the intervals taken by earthquake waves to travel from their origin to distances up to 10° (1111.1 kilometres) deduced from the records of twenty-four Japanese earthquakes.

Distance in Degrees	Commencement of Preliminary Tremors				Commencement of Principal Portion	
	Interval	Diff.	Interval	Diff.	Interval	Diff.
1	M. s. 0 21	s. 18	M. s. 0 29	s. 24	M. s. 0 29	s. 29
2	0 39	18	0 53	18	0 58	29
3	0 57	18	1 11	15	1 27	29
4	1 15	15	1 26	13	1 56	29
5	1 30	9	1 39	12	2 25	30
6	1 39	11	1 51	10	2 55	29
7	1 50	10	2 1	8	3 24	29
8	2 0	12	2 9	6	3 53	29
9	2 12	6	2 15	3	4 22	29
10	2 18		2 18		4 51	

Two groups of times were dealt with, P_1 and P_2 , of Japanese seismologists. The first of these represents the commencement of the preliminary tremors, and two columns are devoted to it in the table: the first represents the measurements of a curve drawn so as to average the records at each distance most closely. It is convex upwards, indicating a slower rate of propagation as the epicentre is neared, but the irregularity of the differences of time for equal differences of distance suggests that it departs from the true time-curve. Another curve was accordingly drawn, representing the average of the observations almost as well as the first, while the more regular decrease in the differences, as seen in the second column, indicates that it is a closer approximation to the true curve than the other. Both columns give unduly high rates of transmission at the longer distances, the curves being uncertain, beyond 7°, from paucity of records.

¹ *Publications of the Earthquake Investigation Committee in Foreign Languages*, No. 18, Tokyo, 1904.

The second group of times dealt with is the P_3 , or commencement of the principal portion of the disturbance. These records group themselves most satisfactorily along a straight line, representing a rate of transmission of about 29.1 seconds per degree of arc. Professor Imamura does not record the time of maximum, but this would be later by about five or six seconds per degree. Probably 35 seconds per degree represents very closely the true rate of propagation.

It must be remembered that only four out of the twenty-four earthquakes dealt with originated on, or so near, land that the place and time of origin could be determined with accuracy by direct observation. The other twenty originated under the sea, and their time and place of origin had to be inferred, with a consequent liability to error in each case; but these errors probably compensate each other to a great extent, and, used with judgment, it is believed that the table will prove useful.

X. *Diurnal Changes in Level at the Royal Alfred Observatory, Mauritius.*
By T. F. CLAXTON.

A Milne seismograph for recording unfelt earth-tremors has been in use at the Royal Alfred Observatory, Mauritius, since September 1898. It was first mounted in a small wooden hut, 12 feet square by 18 feet high, on a brick pillar built up from a concrete floor 9 inches thick; but it was found that with this mounting a very large diurnal inequality of level was recorded, a daily range of 8'' being of frequent occurrence, and during heavy rains the boom occasionally drifted off the sheet.

A more substantial foundation was constructed in November 1899. The pillar was removed, and a hole dug 6 feet deep by 4 feet square; this was filled up with 4 feet of concrete, and a tapering column built up from the latter without touching the earth on any side.

In addition to the wanderings of the boom due to unstable mounting, the registers are vibrated at night and early morning by tremors, which appear to be due to radiation from the concrete pillar, the tremors being most active during rapid cooling. In order therefore to decrease the daily range of temperature within the hut in the month of March 1900, the latter was completely enclosed by a straw thatching at a distance of 3 feet from the walls and roof; but this did not entirely destroy the tremors, and the nocturnal radiation was further checked by means of a lamp which, lighted before sunset and extinguished soon after sunrise, has remedied this defect, but has unfortunately introduced another.

For the study of the diurnal and secular change of level a second pendulum, registering N.-S. tilting, was added to the instrument in February 1904,¹ and a preliminary discussion of its records revealed a well-marked tilt to south, commencing at the time of lighting the lamp.

It is not easy to distinguish the effect of the lamp on the E.-W. boom, as the turning-points occur at about the times of lighting and extinguishing the lamp. The effect, if any, would be to accelerate both morning and afternoon turning-points, as the boom is at its most easterly position when the lamp is lighted, and most westerly when the lamp is extinguished. In the E.-W. records, as affected by the lamp, the afternoon turning-point

¹ This pendulum registers on the same cylinder as the E.-W. pendulum, with which its booms run parallel. The discs at the end of the booms have been reduced in width to 15 mm. Silk threads stretched across the registering slit at every second millimetre produce a fine scale on the paper, by means of which the hourly ordinates are readily and accurately measured.

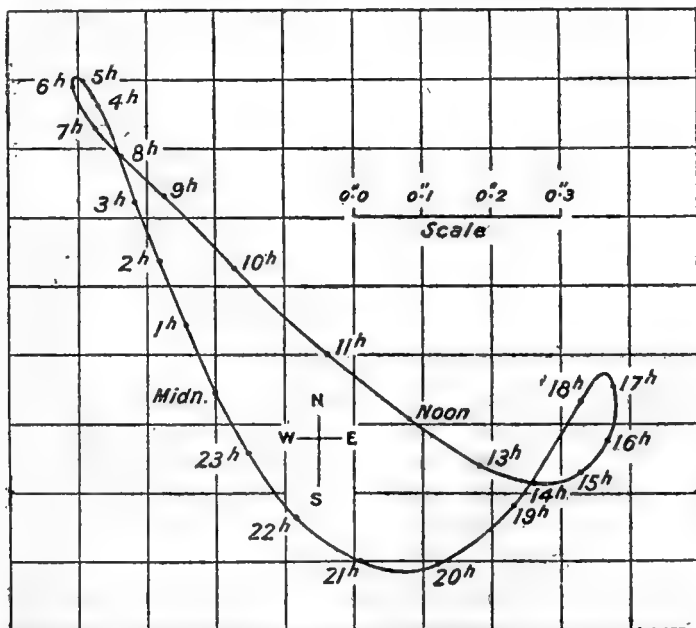
occurs two hours later than in the N.-S. records, occurring in the latter about two hours before the lamp is lighted.

It appears from the above that with the seismograph exposed to the ordinary diurnal range of temperature the registers are affected either by air tremors or by the lamp introduced to check them. For this reason, in the month of July 1904 the instrument was removed to the magnetic basement, in which the diurnal range of temperature is seldom greater than $0^{\circ} \cdot 2$ (Fahrenheit), the chamber having double walls, with an eighteen-inch air-space between them, and its floor being 12 feet below the surface of the ground. The chamber is ventilated by means of a 12-inch pipe laid at a depth of 11 feet below the surface of the ground, and communicating with the air at a point 35 yards distant. A hole was dug, 10 feet deep by 3 feet square, and filled up with 7 feet of concrete, on which a tapering column, also of concrete, was built up to a height of 3 feet above the floor for the reception of the seismograph.

The registers obtained with this installation show no air tremors whatever. No measures have yet been made, but from an examination of the photographs it would appear that the character of the diurnal inequality of level has altered considerably. Its amplitude is very much less than formerly, and the maximum tilt to east occurs at about 8h. in place of at 17h., and the maximum northerly tilt at about 17h. in place of at 6h.

The accompanying vector diagram (fig. 2) shows the mean diurnal tilt of the boom for the year 1903, as determined from the hourly measures of the north and east components. The effect of lighting the lamp (at about 5½h. P.M.) is to tilt the pillar towards the south, and thus reverse the northerly tilt, which sets in after 14h., and to form a closed loop, but there is no corresponding tilt to north when the lamp is extinguished at 6 A.M., the boom tilting steadily towards the south-east until 2 P.M.

FIG. 2.—*Mean Diurnal Inequality of Level at the Royal Alfred Observatory, Mauritius, in the year 1903. (Mauritius Civil Time.)*



Experiments for improving the Construction of Practical Standards for Electrical Measurements.—*Report of the Committee, consisting of Lord RAYLEIGH (Chairman), Dr. R. T. GLAZEBROOK (Secretary), Lord KELVIN, Professors W. E. AYRTON, J. PERRY, W. G. ADAMS, and G. CAREY FOSTER, Sir OLIVER J. LODGE, Dr. A. MUIRHEAD, Sir W. H. PREECE, Professors A. SCHUSTER, J. A. FLEMING, and J. J. THOMSON, Dr. W. N. SHAW, Dr. J. T. BOTTOMLEY, Rev. T. C. FITZPATRICK, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, Mr. J. RENNIE, Principal E. H. GRIFFITHS, Sir A. W. RÜCKER, Professor H. L. CALLENDAR, and Mr. GEORGE MATTHEY.*

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APPENDIX.— <i>On Methods of High Precision for the Comparison of Resistances.</i> By F. E. SMITH	106

IN the last Report reference was made to a conference of representatives of standardising laboratories which had been invited to meet in Berlin as a preliminary to the more formal Conference on Electric Units suggested at St. Louis.

The question of this preliminary Conference was brought before the Committee at a meeting on October 19, 1905, and attention was called to the importance of Clause (2) of the provisional programme, viz.—

‘ Shall the three units, the Ohm, Ampère, and Volt, be defined independently, or shall only two be defined, and, if so, which ? ’

and it was agreed unanimously that two units should be defined independently, and that these two should be the unit of resistance and the unit of current. The Secretary was instructed to report this to the Conference at Berlin.

This Conference took place in October last at the Reichsanstalt in Charlottenburg, and was attended by representatives from America, Austria, Belgium, England, France, and Germany.

Agenda prepared with great care by the President of the Reichsanstalt were very carefully discussed, and, as a result, the Conference expressed the wish that an International Convention should be summoned in order to arrive at agreement in the electric standards which are in use in the different countries.

The following resolution was further adopted :—

‘ In view of the fact that the laws of the different countries in relation to electrical units are not in complete agreement, the Conference holds it desirable that an official conference should be summoned in the course of a year with the object of bringing about this agreement.’

The Conference further expressed the opinion :—

1. That the information before it is not sufficient to enable it to propose any alteration in the formerly accepted value for the ampère.
2. That the information before it is not sufficient to enable it to lay

down exact directions in respect to the silver voltameter and the standard cell.

3. That if a proposal for a change in the accepted value of the ampère is to be brought from any source before a formal congress to be held later, an agreement in writing on the point should be come to previously between the parties interested. If differences of opinion in the matter cannot be removed, a new preliminary conference should be held.

The same procedure should be observed in regard to the specification for the silver voltameter and the standard cell, in the event of such specifications being submitted to a formal conference from any quarter.

The following formal decisions were agreed to :—

1. That only two electrical units shall be chosen as fundamental units.
2. The international ohm, defined by the resistance of a column of mercury, and the international ampère, defined by the deposition of silver, are to be taken as the fundamental electrical units.
3. The international volt is that electromotive force which produces an electric current of one international ampère in a conductor whose resistance is one international ohm.
4. The Weston Cadmium Cell shall be adopted as the standard cell.

Recommendations were also made as to realising the ohm, and some particulars as to the Cadmium cell were agreed upon.

These results were laid before the Board of Trade, and a Departmental Committee, of which the Secretary was a member, drew up a report recommending that an official conference should be invited to meet in London, and it is understood that negotiations are now on foot with view to summoning such a conference.

During the year the work in connection with the absolute ampère balance has been in progress, and is practically complete. Under the supervision of Professor Ayrton and Mr. Mather a large number of determinations have been made, and are most satisfactory. Detailed particulars are reserved until the work is complete ; but there is little doubt that the balance is a most excellent absolute instrument, and that the probable error of a determination of current by means of it is only a few parts in 100,000.

The investigation of the silver voltameter has been extended beyond the limits originally thought to be necessary. The results so far obtained are very valuable, and appear to indicate that a satisfactory form of silver voltameter is realisable. It is hoped that the publication of the results will take place at the same time as those of the ampère balance.

An Appendix by Mr. F. E. Smith describes the methods of comparing resistances in use at the National Physical Laboratory, and discusses the sources of error and the accuracy attainable.

The grant of 25%. made in 1905 has been expended in materials for the work on the ampère balance and the silver voltameter. In connection with the latter a large amount of work involving considerable expense remains to be done. For this purpose the Committee ask for reappointment with a grant of 50%. They recommend that Lord Rayleigh be Chairman and Dr. R. T. Glazebrook Secretary.

APPENDIX.

On Methods of High Precision for the Comparison of Resistances.
By F. E. SMITH.

(From the National Physical Laboratory.)

The object of the author is to give a brief account of the high precision methods used at the National Physical Laboratory for measuring standard resistances. Up to and including the year 1903, the standard unit coils of the British Association were compared by Carey Foster's method, the Fleming circular wire bridge being used. The probable error of such comparisons is of the order 0.001 per cent. The build-up of a 10-ohm coil from the unit was very conveniently effected by a process suggested by Lord Rayleigh.¹ Three 3-ohm coils are arranged in parallel, and their combination value determined by comparison with a unit resistance. They are then placed in series; by the addition of a unit coil to the series formation, the 'build-up' is complete. The probable error of this build-up is also small, but when combined with the error of comparison of nominally equal coils, the observed value of a 1 to 10 ratio may be in error by 0.002 per cent. The use of this ratio for the evaluation of resistances of 10^n units results in a possible error of $n \times 0.002$ per cent.

The resistance standards of the National Physical Laboratory are of three kinds—mercury, platinum-silver, and manganin. When comparing standards of mercury and of platinum-silver, comparatively small currents must be employed, because the temperature-coefficients of these materials are large and the resistances are surrounded by bad thermal conductors. The manganin coils are wound on brass cylinders, have small temperature coefficients, and may be immersed in oil; the maximum permissible current is therefore much greater. The accuracy of all methods of comparison is directly proportional to the current employed, from which it follows that for all building-up processes, manganin coils are to be preferred. The question of preference for permanency is not discussed in this paper.

In order to compare the various methods of measurement it is necessary to give the formulæ for sensitiveness. In presenting these latter I do not wish to suggest that they are new. The subject has been previously treated by Mr. O. Heaviside,² Mr. T. Gray,³ Lord Rayleigh,⁴ Professor Schuster,⁵ Professor A. Gray,⁶ Dr. Jaeger,⁷ Dr. St. Lindeck, Diesselhorst, and others, and some of the formulæ are given in text-books. In the present paper the considerations of many of these writers have been extended. Professor Schuster first pointed out that it is the heating of the conductors which puts the limit to a measurement of resistance, and the formulæ derived by him are in terms of the current conveyed by the resistance to be measured. Dr. Jaeger has recently discussed the question of sensitiveness from the same point of view, and in this paper the subject is similarly treated. The formulæ may be derived in several ways, as will be seen on reference to the authorities quoted. Many of these ways are long,

¹ *Phil. Trans.*, 1883, 174, 310. See also *B.A. Report*, 1883.² *Phil. Mag.*, 1873, xlv., p. 114.³ *Ibid.*, 1881, xii., p. 283.⁴ *Proc. Roy. Soc.*, 1891, 49, 203.⁵ *Phil. Mag.*, 1894, p. 175.⁶ *Absolute Measurements*, vol. i., p. 331.⁷ *Zeitschr. Instrumentenk.*, March 1906, 26, 69. See also Jaeger, St. Lindeck, and Diesselhorst, *Zeitschr. Instrumentenk.*, 1903, 33.

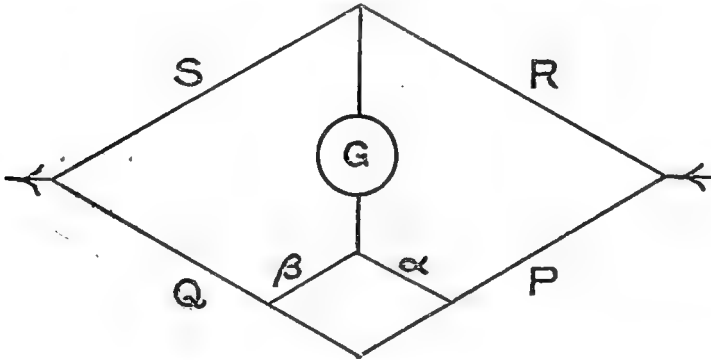
and it may not be out of place to give a well-known rule which, if applied to any system of conductors, will quickly give all the desired information.

‘In any network of conductors the current in one arm due to an electromotive force in another arm is equal to the current in the latter when an equal e.m.f. is placed in the former.’

(This rule results from an application of Kirchoff’s Laws.)

The most complicated system of conductors considered in the present paper is that known as the Kelvin double bridge,¹ and this is dealt with here by way of example. Let the current through P be i , and through R, i' , and let $P/Q=R/S=a/\beta$. Also let the applied e.m.f. remain

FIG. 1.



constant. On completing the galvanometer circuit the distribution of the currents will remain unaltered. Let P be changed to $P + \delta P$. The current through it will change to $i - \delta i$, and the change in p.d. of P is $i\delta P - P\delta i$; of Q it is $Q\delta i$. If the galvanometer circuit is now completed the current through it will be equal to that produced by an e.m.f. $i\delta P - P\delta i$ in P and an e.m.f. equal to $Q\delta i$ in Q. If an e.m.f. equal to the latter is placed in the galvanometer branch, the current through Q is $PQ\delta i / (P + Q)r$, where r is equal to

$$\frac{\alpha\beta}{\alpha + \beta} + \frac{(P + R)(Q + S)}{P + R + Q + S} + G,$$

i.e. the resistance of the ‘external galvanometer circuit’ plus that of the galvanometer. Similarly the current through P due to an e.m.f. $P\delta i$ in the galvanometer branch is equal to $QP\delta i / (P + Q)r$. Hence, by the rule, the current through the galvanometer due to an e.m.f. $Q\delta i$ in Q, is equal to the current through the same due to an e.m.f. $P\delta i$ in P. As these must be in opposite directions through G, we have only to consider the current due to an e.m.f. $i\delta P$ in P. The current through G due to this e.m.f. is found in a similar manner and is equal to

$$\frac{i\delta P}{G + \frac{\alpha\beta}{\alpha + \beta} + \frac{(P + R)(Q + S)}{P + R + Q + S}} \cdot \frac{Q + S}{P + R + Q + S} \quad \dots \quad (A)$$

This, therefore, is the current through the galvanometer when the balance of the bridge is disturbed by an alteration in P of δP .

¹ W. Thomson, *Phil. Mag.*, 1862, 24, 149.

In galvanometers, the coils of which are wound in similar channels, and contain the same mass of wire, the electromagnetic force on the needle, and hence the deflection, is proportional to $x\sqrt{G}$,¹ where x is the current through G . In the case considered the deflection is proportional to

$$\frac{\sqrt{G} i \delta P}{G + \frac{\alpha\beta}{\alpha + \beta} + \frac{(P+R)(Q+S)}{P+R+Q+S}} \cdot \frac{Q+S}{P+R+Q+S} \quad . \quad . \quad (B)$$

This is a maximum when $G = \frac{\alpha\beta}{\alpha + \beta} + \frac{(P+R)(Q+S)}{P+R+Q+S}$, *i.e.* the resistance of the 'external galvanometer circuit,' and the value of this is the most suitable galvanometer resistance. Substituting this value for G in (B), an expression is obtained which, from the conjugate condition of the arms of the bridge, may be reduced to the simple form

$$i \Delta \sqrt{P}/2 \sqrt{\frac{(R+S)(P+R+\alpha)}{PS}} \quad . \quad . \quad . \quad (C)$$

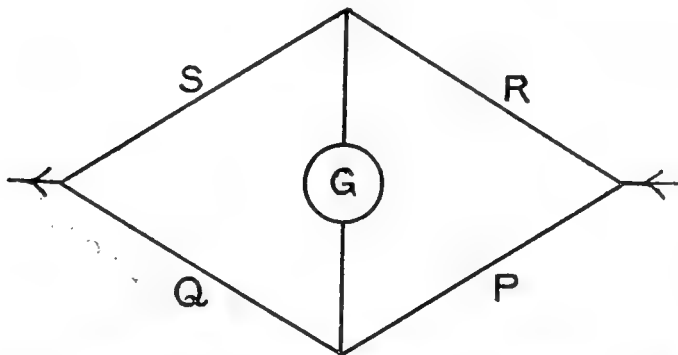
in which $\Delta = \delta P/P$.

If in (B) we write g for the best galvanometer resistance and Ng for the resistance of the galvanometer used, the deflection is proportional to $\sqrt{Ng}/(N+1)\sqrt{g}$, and the ratio of this to the maximum ($N=1$) is $2\sqrt{N}/(N+1)$. Prof. Schuster, in the paper referred to, gives a table showing that if $N=20$ or 0.05 , the sensitiveness is 0.426 times the maximum.

The derivation of the formulæ being so simple, the results alone are given for the other methods considered.

Wheatstone Bridge (fig. 2).—If $\alpha = \beta = 0$ in the expressions obtained

FIG. 2.



for the Kelvin double bridge, the values are those for the Wheatstone bridge.² In this case, expression (C) may be written

$$i \Delta \sqrt{P}/2 \sqrt{\left(1 + \frac{R}{S}\right) \left(1 + \frac{R}{P}\right)} \quad . \quad . \quad . \quad (D)$$

¹ *Absolute Measurements*, A. Gray, vol. ii.

² The values usually given for the Wheatstone bridge (see J. J. Thomson, *Elements of Elec. and Magnetism*, p. 305; Fleming, *Handbook of Elec. Laboratory*, vol. i., p. 233; A. Gray, *Abs. Measurements*, vol. i. p. 333), involve the resistance of

The best conditions for sensitiveness are here clearly indicated. The resistance R should be small compared with S and with P , *i.e.* P should be connected to a comparatively large resistance Q and a small resistance R . If i is the maximum permissible current through P , Q must be a resistance of large cooling surface and small temperature coefficient; if it is of the same type and dimensions as P , then it should be of the same nominal value. In the latter case, which is the general one for precision measurements, $P=Q=R=S$, and the sensitiveness is proportional to $i\Delta\sqrt{P}/4$. It is generally recognised that for coils of the same type and dimensions $i\sqrt{P}$ is constant.

The Potentiometer (fig. 3).—Let the resistances of the two circuits be $P+R_1$ and $Q+R_2$. If i is the current through P , the current through the galvanometer is

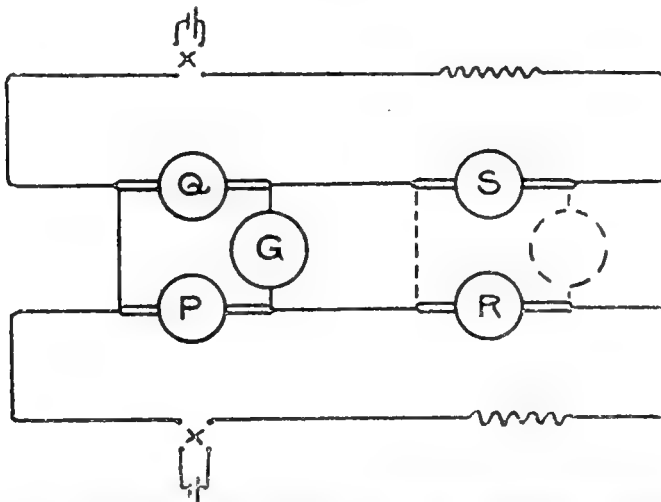
$$\frac{i\Delta P}{G + PR_1/(P + R_1) + QR_2/(Q + R_2)}$$

and the best resistance for the galvanometer is $PR_1/(P + R_1) + QR_2/(Q + R_2)$. The sensitiveness is therefore proportional to

$$\frac{i\Delta\sqrt{P}}{2\sqrt{R_1/(P + R_1) + QR_2/P(Q + R_2)}}$$

In the case of precision measurements, R_1 and R_2 may be made very great compared with P and Q respectively. If this is so, the sensitiveness is proportional to $i\Delta\sqrt{P}/2\sqrt{1 + Q/P}$. If Q is small compared with P , this becomes $i\Delta\sqrt{P}/2$, and the best resistance for the galvanometer is P .

FIG. 3



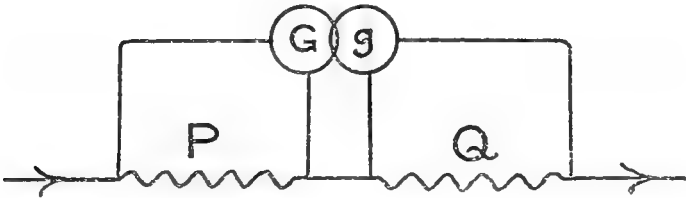
Unless P and R are nominally equal the galvanometer resistance cannot be the most suitable for both observations, and the sensitiveness of one of the measurements must be less than that stated. If $P=R$ and $Q=S$, the latter being comparatively small, the sensitiveness is twice that of the Wheatstone bridge with equal arms. It has to be remembered,

the battery arm and the e.m.f. of the battery. If for the latter $i(P+Q)$ is substituted, the resistance of the battery may be taken as zero, and on substituting, the value given in this paper is obtained.

however, that the current in the potentiometer is continuous and the heating effects more marked than in the bridge in which a tapping current only is employed. A great practical advantage of the bridge method is the rapidity of measurement.

Differential Galvanometer Method (fig. 4).—If G and g are the resistances of the galvanometer coils, the difference of the currents

FIG. 4.



through them is $i(Pg - QG)/G(Q + g)$. If $P = Q$ and $G = g$, the difference of the currents is $i(P - Q)/(Q + G) = i\delta P/(Q + G)$, and the best galvanometer resistance is $G = P = Q$. The sensitiveness is then proportional to $i\Delta\sqrt{P}/2\sqrt{2}$. If the currents through the galvanometer are comparatively large, convection currents are produced in the space containing the suspended magnets; also, the resistance of the coils is subject to small but rapid changes. There is, therefore, a maximum permissible value for the currents through the galvanometer coils, and in general some ballast resistance must be added to the galvanometer arms. This reduces the sensitiveness.

Mercury Standards of Resistance.—The Kohlrausch differential galvanometer (see p. 120), the Kelvin bridge, and the potentiometer have been employed¹ for the measurement of resistance of mercury standards with current and potential leads of comparatively high resistance. These methods are recommended in the Report of the Conference on Electric Units at Charlottenburg (1905). The current used in the measurement of such resistances is limited by the condition that the mercury shall not be sufficiently warmed to produce appreciable error.

In the Standards Department of the National Physical Laboratory no favourable opportunity has arisen for an exhaustive test of the Kohlrausch method. As used at the Physikalisch-Technische Reichsanstalt it is very satisfactory; but, strictly speaking, it is not a null method, as observations of deflections have to be made. From particulars published,² a favourable arrangement for the measurement of mercury standards is when $G = g = 6$ ohms, $P = Q = 1$ ohm, and the ballast resistance in each galvanometer arm is 10 ohms. In this case the sensitiveness is proportional to $i\Delta\sqrt{12}/34 = 0.098 i\Delta$.

With the Kelvin double bridge, if $R = S = 1000$, $P = Q = 1$, $a = \beta = 100$, and $G = 1000$, the sensitiveness is proportional to $0.011 i\Delta$. If $R = S = 100$, $P = Q = 1$, $a = \beta = 100$, the sensitiveness is more than doubled, being equal to $0.025 i\Delta$. This latter case is convenient in practice.

In the potentiometer, if $P = Q$, and $G = P + Q$, the sensitiveness is proportional to $0.35 i\Delta$. The current is continuous, and hence the

¹ *Wissenschaft. Abhand. d. Phys.-Tech. Reichsanstalt*, 414, Band II.; see also *Phil. Trans.*, 1904, A 373, 57.

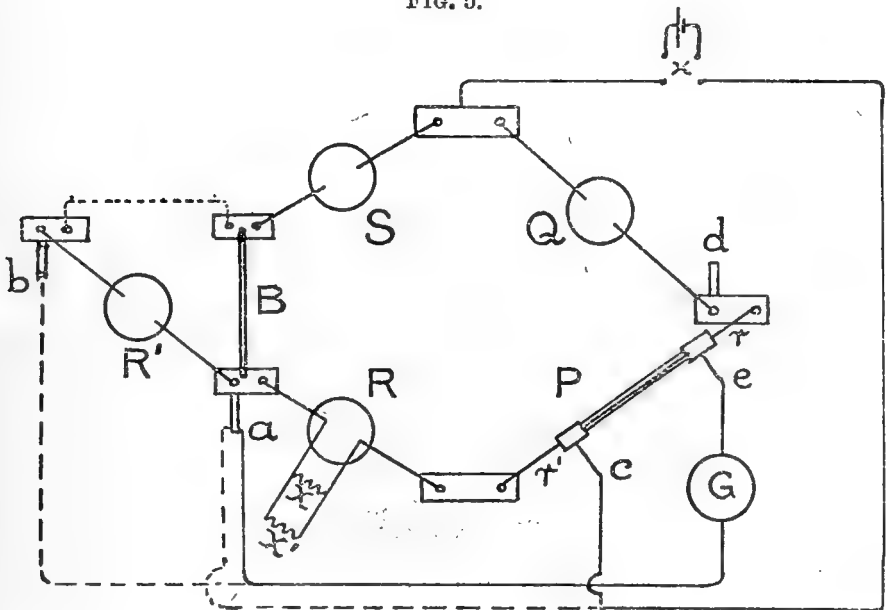
² *Wissenschaft. Abhand. d. Phys.-Tech. Reichsanstalt*, Band III.

maximum permissible value of i is not so great as with the differential galvanometer and Kelvin bridge.

At the National Physical Laboratory the Kelvin bridge and the potentiometer were employed up to March of the present year. With the former method a tapping current of 0.2 ampère was necessary in order to measure a difference of 1×10^{-6} ohm with certainty. With the latter method the current used was 0.03 ampère, but the method was far less convenient. At the present time a modification of the Wheatstone bridge is used, and proves to be the most satisfactory and most sensitive of all the methods discussed. The arrangement is very similar to that suggested by R. H. Housman for the evaluation of small resistances (p. 117).

In fig. 5, P is the mercury standard, of which r and r' are the current leads. R principally consists of a 1-ohm manganin coil which is shunted with a resistance X, usually of the order 30 to 50 ohms, and a resistance X' of several thousands of ohms. The latter is varied in the final

FIG. 5.



adjustment of this arm of the bridge so as to obtain a very accurate balance. Q and S are 1,000-ohm coils of manganin. R' consists of two unit coils in series; the value of these in terms of other unit coils is known with great accuracy (see build-up method, p. 104). B is a thick copper conductor in series with S. The current through P is 0.03 ampère. The operations are as follows: The bridge-piece B is placed in position so that R' is out of circuit, and the shunts X and X' are adjusted until

$$R_1/P = (S+B)/(Q+r),$$

R_1 being the shunted value of R. The galvanometer lead at a is removed and connected to b , and the battery lead at c is placed at a . In practice this change is effected with a rocking commutator. The position of B is altered so as to include R' as one of the arms of the bridge,

and a balance is obtained by shunting R' , when, if R_1' represents the shunted value of R' ,

$$R_1'/(P + R_1) = (S + B)/(Q + R).$$

Combining this with the previous equation, we have

$$R_1' = P[(S + B)(Q + S + r + B)/(Q + r)^2].$$

The value of r is obtained with considerable accuracy by moving the galvanometer lead at e to d and balancing. In an analogous manner the value of B may be obtained; the correction due to B is usually less than 1 part in 10,000,000. The ratio of S to Q may be eliminated from the last equation by interchanging Q and S in the bridge and repeating the operations indicated above. If Q and S are not very different from their nominal values, then

$$R_1' + R_2' = P[4 - 6(r - B)/Q],$$

where R_2' represents the second shunted value of R' .

With a galvanometer resistance of 2 ohms, with $P = R = 1$, and $Q = S = 1000$, the sensitiveness of the arrangement is proportional to $0.35 i \Delta$. With $P = R = 2$, and $Q = S = 1000$, this is increased to $0.47 i \Delta$, the values for i being the same in the two cases. If a greater current value than 0.03 ampere is permissible, then $Q = S$ may be made equal to 100 ohms, and the increase in sensitiveness is approximately proportional to the increase in the current.

The following observations were made on May 30, 1906, the mercury standard, Y , being used, and two coils in series (C.1) evaluated:—

1st observation, $P = Y = 1.00027_0$ int. ohms $Q = 1000.18$ approx.

$S = 1000.19$ „

$X = 40.1$

$X' = 30900$

Shunt on $R' = 31500$. $r = 0.033$. $B = 0.00007$

2nd observation, Q and S interchanged

$X = 40.1$

$X' = 28400$

Shunt on $R' = 16400$.

Hence

$$R_1' + R_2' = 1.00027_0 [4 - 6(0.0000329)]$$

$$= 4.00088_{25}$$

$$\therefore 2R' = 4.00088_{25} + 2(1/31500 + 1/16400)$$

$$\therefore C1 = R' = 2.00053_4 \text{ int. ohms. } t = 17^\circ 21C.$$

Comparing the various methods as practically employed, the sensitivities are proportional to

$0.025 i \Delta$ for the Kelvin double bridge.

$0.098 i \Delta$ „ Kohlrausch differential galvanometer.

$0.35 i \Delta$ „ Wheatstone bridge.

$0.35 i \Delta$ „ Potentiometer.

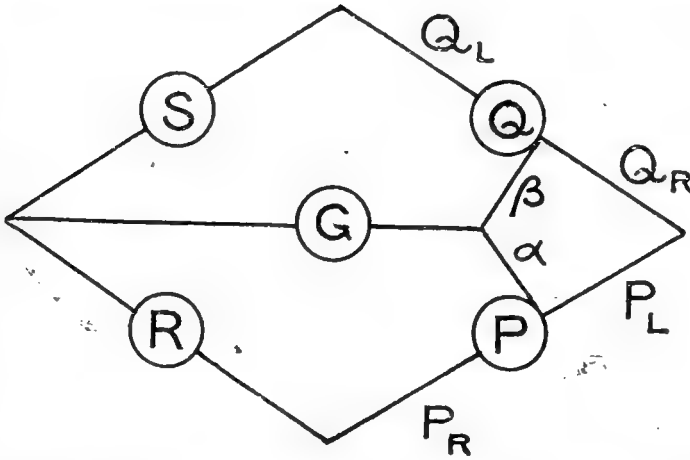
The maximum permissible values of i are the same for the first three methods. For the potentiometer a smaller current must be used. Possibly the arrangement considered for the differential galvanometer might be modified so as to make the method more sensitive.

Comparison of Unit Coils.—Manganin coils with potential points are alone considered. Platinum-silver coils without such points are compared with manganin ones by substitution in one of the arms of the bridge.

The method adopted is analogous to that of Carey Foster. The coils are exchanged in position, but the difference of values is given by the shunts applied to the two ratio coils. Thermal e.m.f.'s are small, and produce no disturbing effect as the galvanometer circuit is continually closed. The self-induction of the coils is very small indeed.

For coils having potential leads the Kelvin double bridge is used. $P=Q$ are the coils to be compared, $P_R, P_L, Q_R,$ and Q_L being the resistances of the current leads of these coils. R and S are 1-ohm standards.

FIG. 6.



$\alpha=\beta=1$ ohm and $Q_R+P_L=d$. The galvanometer is permanently connected as shown in fig. 6, but the battery leads are successively joined to the junctions of $P\cdot P_R$ and $Q\cdot Q_L$, $P\cdot P_R$ and $S\cdot Q_L$, $R\cdot P_R$ and $Q\cdot Q_L$. The coils R and S are shunted to effect a balance. Representing the shunted values of R and S by $R_1, R_2, R_3, S_1, S_2, S_3,$ &c., we have

$$(1) P = \frac{Q(R_1 + P_R)}{S_1 + Q_L} + \frac{d\beta}{\alpha + \beta + d} \left(\frac{R_1 + P_R}{S_1 + Q_L} - \frac{\alpha}{\beta} \right).$$

$$(2) P = \frac{(Q + Q_L)(R_2 + P_R)}{S_2} + \frac{d\beta}{\alpha + \beta + d} \left(\frac{R_2 + P_R}{S_2} - \frac{\alpha}{\beta} \right).$$

$$(3) P = \frac{QR_3}{S_3 + Q_L} - P_R + \frac{d\beta}{\alpha + \beta + d} \left(\frac{R_3}{S_3 + Q_L} - \frac{\alpha}{\beta} \right).$$

In practice, the value of $d\beta/(\alpha + \beta + d)$ does not exceed 0.00006 ohm, and the expression accompanying this is normally of the order 0.00005 ohm, so that the last term in the above equations is negligible. From (1) and (2) $Q_L = (R_1/S_1 - R_2/S_2)/2$, and from (1) and (3) $P_R = (R_3/S_3 - R_1/S_1)/2$.

P and Q are now exchanged in position, when $Q = P(R_4 + Q_L)/(S_4 + P_R)$, the values of Q_L and P_R being determined as before. If the coils are not very different from their nominal values we may now write

$$P - Q = \frac{1}{2}[(R_1 - R_4) + (S_4 - S_1) + 2(P_R - Q_L)],$$

a difference readily determined from the shunts employed. With a galvanometer resistance of 3 ohms the sensitiveness is proportional to $0.20i\Delta\sqrt{P}$. For coils without potential leads, in which case the method of comparison is simplified, the sensitiveness is $0.25i\Delta\sqrt{P}$, the same as for the Carey-Foster bridge employing equal coils and a galvanometer resistance of 2 ohms. The latter method is, however, inapplicable to coils with potential leads, necessitates a calibration and standardisation of the bridge wire, is more troublesome in practice, and the accuracy is limited, not by the general arrangement of the bridge arms but by the openness of the bridge wire and the accuracy of the scale and vernier.

The following table gives the difference in values of four coils with potential leads, every possible combination being taken. The differences in the first column result from the exchanging of the coils in the bridge arms; the differences in the second and third columns are deduced from observations of the two coils with a common standard. Thus, from the first and second recorded observations, the difference 2206-2205 is 130×10^{-7} ohm. The probable error is of the order of 1 part in 10,000,000. The temperature coefficients of these four coils are not very different, and average 0.001 per cent. per 1° C. The bath used for the comparison is that described in the *Phil. Trans.*, A 373, p. 87, 1904.

1905	Coils	Tempera- ture of Observa- tion	Difference at 17° C.			Mean
			1×10^{-7} Ohm.			
July 21 . . .	2351-2205	17.01 C.	492	493	492	492
" . . .	2351-2206	16.96 "	425	424	426	425
" . . .	2483-2351	16.86 "	143	143	144	143
" . . .	2483-2205	17.10 "	635	635	637	636
" . . .	2483-2206	17.12 "	569	568	567	568
" . . .	2206-2205	17.06 "	068	067	066	067
September 8 . . .	2351-2205	17.25 "	475	474	476	475
" . . .	2351-2206	17.22 "	345	344	344	344
" . . .	2483-2351	17.19 "	357	356	356	356
" . . .	2483-2205	17.33 "	831	832	832	832
" . . .	2483-2206	17.38 "	701	702	700	701
" . . .	2206-2205	17.30 "	131	130	130	130

The differences recorded above indicate that at least three of the four coils changed between the dates of the observations. In a similar manner, very small changes have been observed in a few coils in an interval of twenty-four hours. Such changes are very interesting, but cannot be discussed here.

Ten, 100, and 1000 ohm Coils and Resistances of a Higher Value.—By the bridge method the probable error in the evaluation of a resistance of 10^n ohm is n times the error of the 10 ohms built up from the unit. This latter error must, therefore, be made as small as possible. The 'build-up' should contain no variable contacts, and the lines of flow in the coils when these latter are evaluated singly should be practically identical with the lines of flow when the coils are in series. At the National Physical Laboratory three special build-up boxes have been

constructed. The 10-ohm build-up is here described. In this the coils are of nominal value, 1, 1, 2, 2, 5 ohms, and may be described as 1α , 1β , 2α , 2β , and 5. Each coil is of manganin, is immersed in oil, and connected by two copper posts to massive copper blocks, the blocks being provided with side terminals and mercury contacts. The coils 1α and 1β are evaluated by the Kelvin double bridge as described for standard unit coils. The leads to the bridge are from the mercury contacts, and the connections with the shunt coils α and β are from the side terminals. The resistance thus measured is that between two points lying centrally under the mercury contacts in the copper blocks. The value of the 5, 2β , 2α , and 1β in series will, therefore, be exactly equal to the sum of their individual values. The coils 1α and 1β ; 1α , 1β , and 2α ; 2α and 2β ; and 1β , 2α , 2β , and 5 are compared by forming a simple bridge, the coils in the other arms being of 10 ohms resistance. A reversal in position of the two coils enables the difference to be accurately found. Finally the 5, 2β , 2α , and 1β are employed to evaluate a 10-ohm coil. 100 and 1000 ohms are built up in a similar manner.

Let the constructional errors of the 10, 100, and 1000 ohms build-up boxes be a , b , and c respectively. Then, if we neglect the errors of observation, which are small, the error of a 10-ohm is a , of a 100-ohm ($a+b$), and of a 1000-ohm ($a+b+c$). If the 100 and 1000 ohm coils are evaluated by a Wheatstone bridge using the 10 to 1 ratio, then the error of the 100-ohm is $2a$, and of the 1000-ohm $3a$. Hence, if in practice $a=b$, and $2a=b+c$, the probable error of the built-up values must be very small. Observations show that the differences $2a-(b+c)$, $3a-3b$, &c., are not measurable with certainty, for not only are the observed differences very small, but often the sign changes. The differences resulting in one set of observations is given in the following table:—

June 11, 1906. Observed Values in Int. Ohms at 17° C.

—	L·19	2450	2449
From build-up boxes	9·9997 ₉₇	100·008 ₈	1000·53 ₀
From 1 to 10 ratio by use of Wheatstone bridge		100·008 ₈	1000·52 ₇
From build-up boxes	9·9997 ₉₃	100·008 ₈	1000·52 ₈

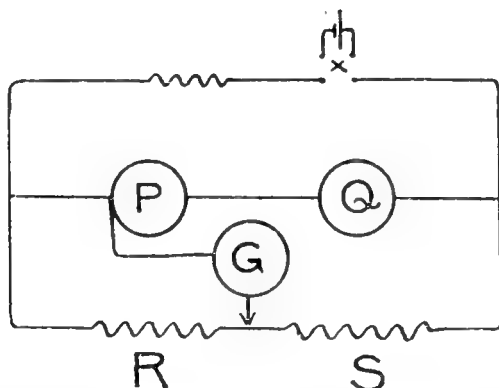
The values given on the first and fourth lines are from the three build-up boxes. The second values of 2450 and 2449 are obtained by the bridge, using the 1 to 10 ratio from the first build-up. The third value of 2449 results from the 1 to 10 ratio from the second build-up, and the probable error is therefore $3b$.

Low Resistance Standards.—A large number of methods have been suggested for the measurement of small resistances, and as many of these are known to be in use, it may be of service to point out the advantages and disadvantages of each.

(a) *Matthiessen and Hockin's Method* (fig. 7).—By adjusting the resistances R and S, a balance is obtained with the galvanometer arm connecting R·S with each of the potential points of P and Q in succession. The value of R+S is kept constant. The ratio of R to S is necessarily

very great in one of the observations, and the sensitiveness is, therefore, very small (see expression (D), p. 108). The method is unsuited for accurate work.

FIG. 7.

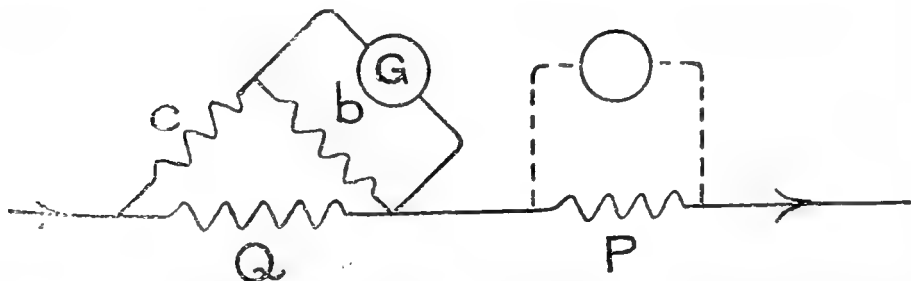


(b) *Method suggested by Lord Rayleigh* (fig. 8).—As an alternative to the previous method, the following process was suggested by Lord Rayleigh in 1884.¹ P is the low resistance whose value is required. Q is a one-tenth-ohm standard which is shunted by the resistances *b* and *c*, the ratio of *c* to *b* being approximately equal to Q/P if the resistance of the galvanometer is comparatively great. When the galvanometer is connected across *b*, *c* is adjusted until the combination gives the same effect upon it as P does. Then, supposing the resistance of the galvanometer branch to remain constant,

$$P = Q + b + c + bc/G.$$

The method may be made a null one by using a differential galvanometer and an additional resistance S (approximately equal to P) in the main circuit. One coil of the galvanometer is connected across P and the other

FIG. 8.



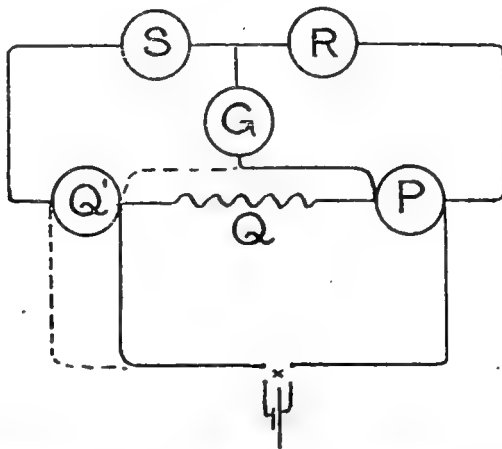
across S, the resistance of the galvanometer arm of S being adjusted until there is no deflection. The P galvanometer coil is then joined across *b*, and *c* adjusted to obtain a balance. Small variations in current strength have no effect, but the current must be reversed and the combination

¹ *Camb. Phil. Soc. Proc.*, 1884, v., p. 133.

readjusted in order to eliminate thermal e.m.f.'s. The resistance of the galvanometer branch is not constant unless the potential leads of P are equal in resistance to those of b . In order to neglect the resistance of these leads, and to make bc/G comparatively small, G must be great. This diminishes the sensitiveness. If Q is made greater than 1, the maximum permissible current in the main circuit is reduced, and the sensitiveness is again diminished. Suppose that $P=0.01$, $Q=1$, $b=1$, $c=97$, and $G=100+x$ where x is small. Then $P=1/(99+0.97-0.01x)$. Hence, if the value of P is desired to be correct to 0.001 per cent., the value of the galvanometer resistance must be known to 1 part in 1000. Although not so sensitive as other methods described hereafter, the process is interesting. The combination of resistances Q , b , and c was used by Lord Rayleigh in the determination of the ohm by Lorenz' method.

(c) *Housman's Method*¹ (fig. 9).—The first stage in the process is to measure the ratio of P to Q by shunting R or $(S+Q')$. The second is to shift one galvanometer lead and one battery lead and measure the ratio of $(P+Q)$ to Q' . Q' is a 1-ohm coil. For precision work the leads connecting Q' to S and P to R must be known. The greatest disadvantage of this method is that the current through P in the second measurement must be comparatively small. Thus, if $P=0.0001$, $Q=0.01$,

FIG. 9.



and $Q'=1$, the maximum permissible current through P (if P is the usual type and size of standard resistance) is 100 ampères; through P and Q in series, 10 ampères; and through $P+Q+Q'$ in series, 1 ampère. The necessary ratio of the arms S and R is also unsuited for accurate work.

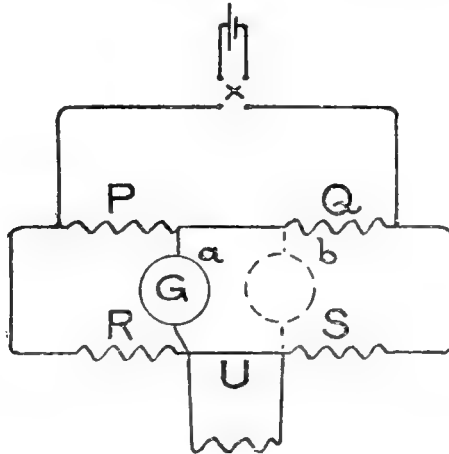
(d) *Two-step Method*² (A. Campbell) (fig. 10).—A suitable small resistance, whose value need not be accurately known, is inserted at U , and is adjusted by shunting until the galvanometer balances in position a . The galvanometer is then brought into position b and balance obtained by another shunt at R or S . By repeating this process a few times the balance is good in both positions. The method is about 50 per cent. more sensitive than the Kelvin double bridge if equally favourable arrangements are made, but it is much less convenient in practice. The leads

¹ *Electrician*, 1897, xl, p. 300.² *Phil. Mag.*, July 1903.

connecting P to R and Q to S have to be evaluated by changing the position of the battery leads.

(e) *Potentiometer*.—With very small resistances, if great sensitiveness is required, two currents of large value have to be maintained in a steady state. As the probable error is proportional to the variation in the current strengths this necessitates great care. In practice the sensitiveness may be made greater than that of any other method. If $P=0.0001$, $R=0.001$, $Q=0.001$, $S=0.01$ (see fig. 3), and if we suppose the resistance of the other portions of the circuits to be comparatively great, then, with

FIG. 10.



$G=1$ ohm, the sensitiveness for one position of balance is proportional to $0.01 i \Delta \sqrt{P}$, and for the second position of balance $0.031 i \Delta \sqrt{R}$. If $Q=1$, $S=10$, the sensitivities corresponding are proportional to $0.005 i \Delta \sqrt{P}$ and $0.0029 i \Delta \sqrt{R}$.

(f) *Kelvin Double Bridge*¹ (fig. 11).—For measurements of precision this method is used at the National Physical Laboratory. Balance is first obtained by shunting R or S, when

$$P = \frac{QR'}{S'} + \frac{\beta d}{a + \beta + d} \left(\frac{R'}{S'} - \frac{a}{\beta} \right),$$

R' and S' representing the shunted values of $R+L$ and $S+L'+L''$. To obtain the value of L the battery lead at P-L is disconnected and joined to L-R and the bridge again balanced. $L'+L''$ is similarly evaluated (see example which follows). For d , a and β are disconnected and the galvanometer circuit completed by connecting to the junction of Q and d and balancing. The ratio of a to β must be known with considerable accuracy if d is comparatively great. a consists of a resistance coil plus a potential lead of P, and β of another coil plus a potential lead of Q; hence the ratio must be determined with a and β in position in the bridge. The bridge is first balanced in the ordinary way by shunting R or S. The connector which joins P to Q through the arm d is then removed and balance restored by shunting a or β . The original arrange-

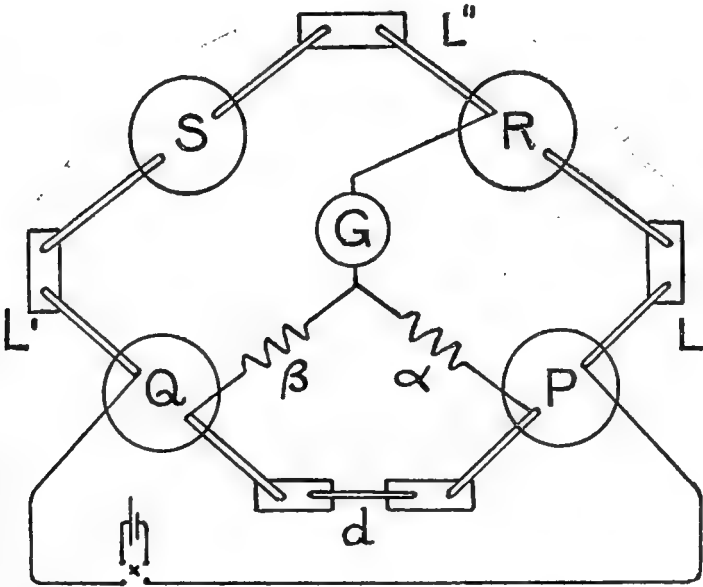
¹ W. Thomson, *Phil. Mag.*, 1862, 24, 149. See also Jaeger, St. Lindeck, and Dieselhorst, *Zeitschr. Instrumentenk.*, 1903, 33.

ment is restored and the bridge balanced again. Thus, by successive approximations we have

$$\frac{P}{Q} = \frac{P+\alpha}{Q+\beta} = \frac{\alpha}{\beta} = \frac{R'}{S'}$$

where R' and S' are the shunted values of R and S . Thus $\frac{R'}{S'}$ is equal to α/β within the limits of the errors of measurement. It does not follow, however, that $d\beta/(a+\beta+d) \times (R'/S' - \alpha/\beta)$ is negligibly small. It is only so if the value of $d\beta/(a+\beta+d)$ does not exceed the value of P . If the value be NP and the probable error of an observation is 1×10^{-n} , then the error of the final result is not less than $N \times 10^{-n}$. It will be seen from this that the current leads of standard resistances intended for measurement on the Kelvin double bridge should have a resistance not greater than the standard itself. In some commercial standards the

FIG. 11.



resistance of the current leads *plus* the connectors necessary for their measurement is greater than that of the standard strip. In such cases the potentiometer or Kohlrausch differential galvanometer should be employed. In the department of Electrotechnics at the National Physical Laboratory the potentiometer is used. The sensitiveness of the Kelvin bridge is less than that of the potentiometer, but it is more convenient in practice. In the bridge, if $P=0.0001$, $Q=0.001$, $R=1$, $S=10$, $\alpha=1$, $\beta=10$, the sensitiveness is proportional to $0.0034 i \Delta \sqrt{P}$. The galvanometer resistance is supposed to be 2 ohms. An example follows. For simplicity $P=0.1$ ohm.

$P = \text{No. 2484} = 0.1$ ohm with potential leads.	Value desired.
$Q = \text{No. 2351} = 1.0$ " " " "	Value = 1.00000_2 at 17.0°C .
$R = \text{No. 2483} = 1.0$ " " " "	Value = 1.00002_4 " "
$S = \text{No. 1693} = 10.0$ ohms. No potential leads.	Value = 10.0001_8 " "
$\alpha = 1$ $\beta = 10$ $t = 17.0^\circ \text{C}$.	

Balance was effected by shunting R with 122,000 ohms. The connector completing the branch d was then removed and balance again established by shunting a with 6,500 ohms. The balance still held good when the connector was restored in position. Hence, if R' and a' represent the shunted values of R and a ,

$$\frac{P}{Q} = \frac{P + a'}{Q + \beta} = \frac{a'}{\beta} = \frac{R' + L}{S + L' + L''}$$

the probable error of these ratios being of the order 0.0001 per cent. in the present instance. The value of d (for measurement see the following table) is equal to 0.00012₈ ohm, and is less than P. Hence

$$P = \frac{Q(R' + L)}{S + L' + L''} = \frac{1.00000_5 \times (1.00001_6 + 0.00011_9)}{10.0001_8 + 0.0001_2} = 0.100011_0 \text{ at } 17.0^\circ \text{ C.}$$

The manner in which d , L, and $(L' + L'')$ were evaluated will be seen from the accompanying table. This is a good instance of a measurement involving a number of connecting pieces which must be evaluated in position.

Position of Galvanometer Leads	Position of Battery Leads	Balancing Condition	Ohm
(1) L'' R $\alpha\beta$	P·L Q·L'	Shunt on R = 122000	Equivalent change = 0.00000 ₈₂
(2) " " "	L·R Q·L'	" " S = 8150	" " = 0.00122 ₆
(3) L''·S "	P·L S·L'	" " R = 7100	" " = 0.00014 ₁
(4) L''·R Q·d	P·L Q·L'	" " S = 8370	" " = 0.00119 ₅

$$\begin{aligned} \text{From (1) and (2)} \quad L &= 10(0.000130_8)/11 = 0.00011_9 \\ \text{" (1) " (3)} \quad L' + L'' &= 10(0.000133)/11 = 0.00012_1 \\ \text{" (1) " (4)} \quad d &= 0.00012_8 \end{aligned}$$

(g) *The Differential Galvanometer.*¹—This method is usually used for comparing resistances which are nominally equal. It is not convenient for their evaluation from the unit by means of a ratio of 1 to 10.

The difference of the currents through the galvanometer coils is $i(Pg - QG)/G(Q + g)$ where G and g are the resistances of the galvanometer circuits (see fig. 4). This is equal to zero when $P/Q = G/g$. When this latter condition holds there will in general be a deflection owing to want of symmetry of the galvanometer coils. If $P=1$ and $Q=10$, then the ballast resistance in circuit with g or G may be adjusted until there is no deflection. In such a case, if two other coils, $P'=0.1$ and $Q'=1.0$, are substituted for P and Q (G and g remaining as before), and ten times the previous current sent through them, there will be no deflection when $P/Q = P'/Q'$. In general, however, the maximum permissible current is $\sqrt{10}$ times that previously employed, and any want of symmetry in the galvanometer coils does therefore introduce an error. In addition, the substitution of P' and Q' for P and Q changes the values of G and g, because these latter include the potential leads of the resistances and also the contact resistances introduced. If G and g are comparatively large, the error is reduced, but so also is the sensitiveness. In the same way, errors are introduced in the comparison of nominally equal

¹ See *Heaviside's Papers*, vol. i. Also C. W. S. Crawley, *Journ. Inst. of Electrical Engineers*, April 1904.

resistances. In this latter case if P and Q are exchanged, P is equal to Q when there is no change in the deflection, and no error is introduced by want of symmetry in the galvanometer coils or inequality of the resistances of the galvanometer circuits, always supposing that these latter remain constant throughout the observations. Unfortunately, the resistances of these circuits do change, for the reason previously given, and the error introduced may be considerable. Let $P=Q=0.1$ ohm, and let the resistance of the leads of $P=0.0001$ ohm, and of $Q=0.0002$ ohm. (In some low resistances the potential leads are of the order 0.01 ohm.) Then if $G=1$, and no correction is applied for the inequality of the leads, the error of measurement is 0.01 per cent. If $G=100$ ohms, the error is 0.0001 per cent., but the sensitiveness is reduced to one-fifth of its former value. Such errors are abolished if the Kohlrausch method of

FIG. 12.

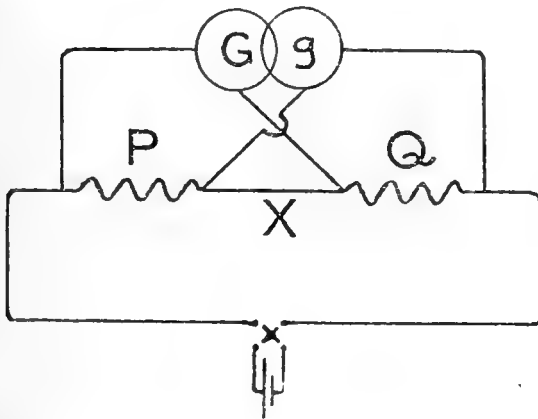
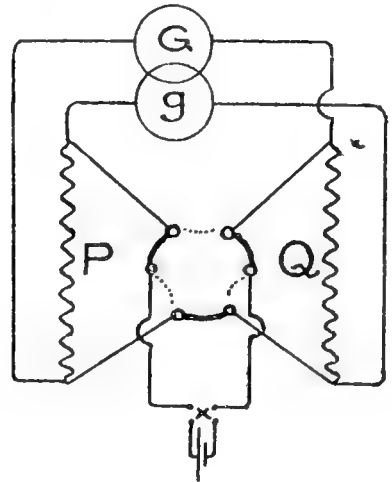


FIG. 13.



overlapping shunts¹ is used, of which a diagram of connections is given in fig. 13. In fig. 12 let $P=Q$. Then, unless there is symmetry of the galvanometer coils and equality of resistance of their arms, there will be a deflection. Supposing that G and g can be exchanged in position by substituting for X a resistance practically identical with it, then the deflection will be of the same magnitude and of the same sign as before. In practice P is made equal to Q by shunting one of them, the equality being determined by the equality in magnitude and sign of the deflection before and after interchanging G and g. The exchange is effected by a six-pole switch as shown in fig. 13. The resistance of the galvanometer circuits is thus constant, and it is apparent that the Kohlrausch method of using the differential galvanometer is the only one so far suggested that can be used for precision measurements.

¹ *Wied. Ann.*, 1883, 20, 76. See also article by Jaeger, *Zeitschr. Instrumentenkunde*, 1904, 288.

The Evolution of the Elements. By F. SODDY.

(Ordered by the General Committee to be printed *in extenso*.)

THE subject chosen for the discussion which I have been asked to open is almost as old as any in philosophy, but the profound change which it has undergone in the last decade makes it desirable to pause, and, looking backward, to review the standpoint that has been attained. I shall attempt to deal briefly with the historical aspect, in the hope of showing how perfectly the newer ideas dovetail into, and arise naturally out of, the hardly-won articles of scientific belief of a generation ago. The new emphatically does not in any sense subvert the old, but the horizon has greatly extended—how greatly is perhaps hardly yet fully admitted. Facts always remain in modern science, and theories too, in so far as they mirror them completely. So the old facts about the atom and element remain; but the theories, which are the generalised expression of all the facts, have had in connection with the discovery of radioactivity to accommodate some new facts of a strange, not to say revolutionary, character. The extension of the theories which has been rendered necessary has not been revolutionary in any destructive sense. It is wonderful how accommodating a true theory is to new truth, apparently of a diametrically opposite character, and this not in any sense of mere ingenuity of explanation, but in a manner that arrests the investigator, and is his sign that he is on safe ground. From the very first the best proof of the newer views, to my mind, was in the completeness with which the strange, newly-won knowledge harmonised with the old, and gave to it a still deeper meaning.

I intend first to consider the distinguishing features of the newer conception of the evolution of the elements, and how it came about that they remained so long unanticipated, either in imagination or discovery. Then the new light that has been shed on some of the oldest problems in the more speculative departments of knowledge must be touched on, and this leads naturally to the question as to what are the limitations of the present position. How far does the new view fail to reveal types of evolution which now may be legitimately imagined to be taking place, and of which the only thing we are certain of is that our present weapons are unequal to the task either of discovering or investigating them? Again, we have to take into account the poverty of the unaided human imagination and the wealth of suggestion that one fundamentally new point of view awakes. From this point of view, it is true, the advance made points to an extension of possibilities so great as almost to amount to a revolution of thought. Possibilities of the ultimate convergence of these newly discovered processes and activities of matter on the practical problems of life and the future welfare of the race, considered in the light of the known effect of the relatively insignificant forces which have already been harnessed and are taking every day a larger place in our lives, lose none of their suggestiveness for being so vague and incalculable. Possibilities of a new order of things, a more extended and exalted material destiny than any that have before transpired, even as possibilities, must affect the imagination and lay hold on the thought of the future none the less even if they continue to remain out of reach. It is in this sense that the new discoveries must affect in time the whole

trend of philosophic thought. We are now, however, more nearly concerned with the lines of attack at our disposal for dealing with the new situation which has presented itself, and in which, it must be confessed, we feel unusually ill-equipped. The weapons available are rather limited in their range, and there is the possibility that the radio-elements may remain for long the only example of a process of evolution which we cannot but believe will ultimately embrace all the elements within its scope, and lead to a consistent theory of the whole material universe.

More than fifteen hundred years ago, as M. Berthelot has pointed out, the symbol by which matter was everywhere expressed was a serpent, the body coiled into a circle and the head devouring the tail, bearing the central motto 'ἐν τὸ πᾶν.' This was derived from the Greeks, who, in imagination, untrammelled by knowledge, far surpassed even the most advanced theory of to-day, supposing that material evolution proceeded in a cycle, and thus were able to arrive intuitively at a system at once continuous, consistent, and eternal, avoiding the inherent difficulties connected with the beginning and end of the process which trouble us to-day. From that time till quite recently, although the idea of continuous evolution of matter was never absent, experimental knowledge advanced steadily along lines which seemed almost to disprove the possibility of any such process. We had Boyle's recognition of an element as a substance which could not be fundamentally changed or made to yield anything more simple, and the continued existence of a relatively few constituent elements throughout all chemical changes. The law of multiple proportions and Dalton's atomic theory led to the idea of atoms, in their modern experimental sense, as the units of all chemical changes—the bricks, so to speak, out of which all molecules are built and into which they can be resolved. The advent of the spectroscope and the evidence afforded by such meteorites as make their way to us from distant regions proved the essentially uniform composition of the material universe.

Intimately connected with these researches another idea took shape as chemistry advanced. Not the slightest variation in the properties of elements could be detected, and hence each atom must be exactly like every other of any one element. It had constants, such as the atomic mass, which is in itself a theoretical abstraction from the experimental combining or equivalent weight, and periods, represented by the characteristic lines in its spectrum, capable of being measured with extreme accuracy, and in which the slightest variation in value had never been detected. An atom of hydrogen executes its vibrations, by which we know it, at precisely the same rate in the most distant star as in the laboratory. This seemed to exclude the possibility of a gradual change or evolution of one element into another. The position cannot be more forcibly expressed than in the familiar words of Clerk Maxwell to this Association at the Bradford Meeting in 1873.

'In the heavens we discover by their light, and by their light alone, stars so distant from each other that no material thing can ever have passed between them, and yet this light tells us also that each of them is built up of atoms¹ of the same kind as those we find on earth.

' . . . Each atom, therefore, throughout the universe bears impressed upon it the stamp of a metric system as distinctly as does the mètre of

¹ I have replaced the word molecule throughout by atom, so as to retain the same meaning for the word atom as it bears throughout the paper.

the Archives of Paris or the double royal cubit of the Temple of Karnac. No theory of evolution can be formed to account for the similarity of atoms, for evolution necessarily implies continuous change, and the atom is incapable of growth or decay, of generation or destruction.

'On the other hand, the exact equality of each atom gives to it, as Sir John Herschel has well said, the essential character of a manufactured article, and precludes the idea of its being eternal and self-existent.'

In this quotation we have the best generalised expression of the philosophy of a generation ago. To-day we could deduce even more striking examples of the exact similarity of atoms than were then known, and yet we believe in evolution as an experimentally demonstrated fact.

A little later the swing of the pendulum was again towards some system of evolution. The discovery of the periodic law, and the natural order into which the elements fell when classed according to their atomic weight, the recurrence periodically of elements resembling each other in properties, these resemblances extending even to similarity of spectrum, together with the growing knowledge of all that the spectrum of an element implied, led to the view that similar elements must possess similar structures, in which the constituent stuff out of which they are built is the same but the quantity and arrangement different in the formation of each atom. The idea was expressed, by the lemniscate curve of Sir William Crookes, that the elements were successively formed out of the same protyle, while in their formation a periodic change of the conditions conditioned the periodic recurrence of properties. A little later Sir Norman Lockyer propounded a theory of inorganic evolution accompanying cosmical evolution, in which in the hottest stars it was concluded the conditions are such that only the lighter elements can exist, and then, as the star cools, the heavier elements successively make their appearance, by the condensation of the lighter.

Finally we have the brilliant series of researches emanating from the Cavendish Laboratory, under J. J. Thomson, in which he succeeded in the isolation and measurement of the constants of the corpuscle or negative electron, and the recognition that this must possess the fundamental attribute of matter, inertia or mass. From this point came the step to the conclusion that negative electricity might be the protyle, out of which all atoms are in some way constructed, by varying numbers being combined together in stable systems in regular motion. But in the more purely speculative part of this theory it is not necessary for me to venture.

I pass to the discovery of the radioactivity of matter by Becquerel and its essential characteristic, which at once arrested attention. Here we had a case of certain of the heaviest elements being proved continually to liberate energy of a very novel and striking character without at first sight any perceptible change in the matter or any exhaustion of the supply. As is well known, this energy is manifested in the emission of new sorts of radiation, and it has been proved that these radiations are in nature much what Newton supposed light to be, consisting of streams of material particles ejected from the matter with hitherto unknown velocities. In general two kinds of radiant particles have been recognised, the α particle, having a mass slightly greater than the hydrogen atom, and the β particle, which is an electron or corpuscle many thousand times smaller.

A theory elucidating the mystery was worked out in the laboratories of McGill University, Montreal, under Rutherford four years ago, and having proved itself adequate to explain the known facts and to suggest innumerable new discoveries, it has received general acceptance. I need only recall the discussion which took place on the subject in this Section three years ago, which assisted materially in the favourable reception accorded the disintegration theory, and in this Section at least I need only briefly refer to its main outlines.

The atoms, in the case of the radioactive elements, are spontaneously breaking up into atoms of lighter elements, and this change proceeds in each case according to a very simple law. The same definite fraction of the total number of atoms breaks up in the unit of time in the case of any one radioactive element. The α particle expelled with enormous velocity consists, as we have seen, of an atom a little heavier in mass than the hydrogen atom, and this it seems probable, though it has not been completely proved, is an atom of helium. The residual atom which is left, in many cases breaks up again and again, the same law as before being followed, only in the succeeding products the fraction changing in unit time is usually much larger than in the original elements, so that the consequence is that these products have a very limited term of existence, and can only accumulate in minute quantities. The energy that is evolved in this change is so enormous that very slow changes can be observed, where the actual amount changing is so infinitesimal that it is hopeless to attempt to detect it by ordinary methods. This appears at once when it is considered that the smallest quantity of any element that can be detected by the spectroscope contains between 10^{13} and 10^{14} individual atoms, whereas the disintegration of a single atom accompanied with the expulsion of one α particle is not greatly, if at all, below the limit of detection by present methods.

At first put forward on radioactive evidence alone, it was not long before additional evidence of the correctness of the view was obtained by the older methods. With the discovery in the laboratories of the University College, London, under Sir William Ramsay, of the production of helium from radium, the fact of the gradual evolution of one element into others passed beyond doubt, and the new methods of investigation received the support of the old in a case where it was found possible to examine the process from both points of view.

The essential features distinguishing the type of evolution revealed by radioactive processes from previous conceptions chiefly claim our attention.

The first consists in the reconciliation of the idea of a gradual evolution of one element from another with the facts of chemistry and spectroscopy, which we have seen were at one time interpreted to prove the exact opposite. On the new view the change, though of any degree of slowness so far as the mass of the matter is concerned, is sudden and abrupt for each individual atom. There is no gradual alteration of one element in properties until it changes into another, but an abrupt, or more usually a series of abrupt, step-by-step changes in property accompanying the sudden expulsion of each α particle. As great a difference exists between radium and its emanation, which is its first product, as between any pair of elements known. Yet it is gradual in the sense that only a small fraction of the total quantity of the radium changes in each unit of time.

Slight as this addition is to make the requirements of chemistry and

spectroscopy conform to those of continuous evolution, yet the words of Maxwell clearly show how small a step the most brilliant imagination, unaided, is able to take. It would be an interesting digression to examine the small part played by the imagination, unaided by existing models or analogies, in mathematical and physical science.

The second distinguishing feature is that the evolution proceeds from the complex to the simple. In all previous ideas a continuous building-up of the original protyle into something more and more complex was implied.

The third difference is that the evolution is actually proceeding under our eyes, instead of having once proceeded in the remote past, or, if proceeding now, then only under transcendental conditions impossible to realise in the laboratory, which was the earlier idea.

But the fourth distinguishing feature is the vital one. Hitherto the energy changes that must accompany a subatomic change had received no consideration, while in the new views it is the dominating aspect. Much takes on a new significance in this light. We have seen how the range of the older weapons of investigation, the balance and the spectroscope, has been left behind. We can understand why it is that these new changes proceed with such complete independence of their environment. All the forms of energy known previously are so much lower in order of magnitude that it is not to be expected that we should be able to influence the rate of change with the means at our disposal. The explanation is now ready to hand why the elements have hitherto resisted and still resist all attempts to change them. The resistless energy which accompanies the break-up of an atom must pre-exist within the atom and be controlling its history, making it independent of its environment and such forces as we can bring to bear upon it from the outside. For the first time we have a positive proof, if such were needed, of the correctness of the stand taken by chemistry against the claim of the alchemist. There may have existed a lingering doubt in some minds, after reading the circumstantial accounts that have been recorded of actual transmutation, that perhaps in some cases the alchemist by chance achieved his ends. Now, however, we know that such could certainly not have been the case, on account of the energy which would have been evolved in the change of a heavy element into a lighter one, or absorbed in the reverse process. On the other hand, we can imagine what consequences the successful transmutation of metals would bring in its train, which are not at all those which its devotees have imagined. In this problem our position might be compared to that of the savage who knew of fire and its possibilities, and yet neither possessed it nor could start or control it. The control and utilisation of fire and other sources of energy means no more to the present than the control and utilisation of the internal energy of matter will mean to the future, if ever it comes to be accomplished.

It is in this aspect also that the most revolutionary changes in previous ideas are rendered necessary. The energy changes accompanying any form of continuous material evolution must be the controlling factor of any cosmical scheme, and the failure to recognise this so deeply affects all the existing views on cosmical and terrestrial evolution that it is difficult to see what will remain when it is rectified. But a beginning has been made, and the discussion that has been arranged in this Section on the connection between radium and the internal heat of the earth must

bring forth fruit abundantly. I need only say I would like to see the whole subject reconsidered, now that it is clear that an isolated body in space need not of necessity get cooler, although continually losing heat.

There is a small question of nomenclature, the retention of the word *atom*, now that atoms have been shown to be changeable, which may appear justified if we consider the history of the word. The Greek meaning conveyed by the word was purely an imaginative one, being, in fact, the smallest particle of matter that can be imagined. From the time of Dalton a new experimental meaning became attached to the word, to signify the smallest part of an element, or the unit, that enters into chemical change, and since chemical changes were the most fundamental then known, the word signified in a derived sense the smallest particle that can exist. To-day the atom still retains the exact meaning it has had for a century, as the unit of chemical change, but chemical change is not now the most fundamental known. Radioactive change is so utterly different that it cannot be considered to have any relation to chemical change.

The view has been expressed to me that since the radio-elements have been shown to undergo changes, it is incorrect any longer to speak of their atoms, and the word molecules would meet the case. But this would cause the word *atom* to drop out of scientific use altogether, for no element is safe from the fate which has been shown to overtake the radio-elements. On the other hand, if we used the word *molecule* throughout where now we use *atom*, and spoke of a molecule of hydrogen where now we mean atom, we should have to revive the old clumsy nomenclature of simple molecules meaning atoms, and compound molecules meaning molecules.

Limitation of Present Methods.—Our knowledge of material evolution has arisen almost entirely on account of the energy emitted in the processes, the material evidence, as in the proof of the production of helium from radium, being of necessity only confined to a few cases. The general condition which determines whether any process of spontaneous evolution comes within our experimental methods of detection is simply that the energy evolved should be sufficient in quantity and suitable in kind. There is no doubt that in the actual case of the radioactive elements the conditions are exceptionally favourable. Probably in no other branch of physics can such a minute evolution of energy be detected and accurately measured as in radioactivity. The electroscope is the oldest and simplest as it is the most sensitive electrical instrument, and in proper hands possesses possibilities for accurate measurement by no means to be despised. It may seem to conflict with what has been said as to the enormous quantities of energy liberated during radioactive processes that such delicate methods should be demanded, but that is because the actual amount of matter changing is always infinitesimal, even under the most favourable circumstances. The world is old, and only those changes which require an aeon for completion continue still.

Since the theory of atomic disintegration was advanced it has become more and more plain that such disintegration may, and does, occur without the accompaniment of radioactivity. We now rather regard radioactivity as a gratuitous hint given us, one might almost say overlooked, by nature into secrets we were not bound ever to have known of at all. For the same result and the same type of evolution could have been accomplished, and may actually be going on, without our possessing any

means to discover or investigate it. Three separate lines of evidence which have lately transpired show this in the clearest possible manner. In the first place, Rutherford proved the existence of changes in the disintegration series of radium, thorium, and actinium in which no detectable radiation was expelled. Let A change into B, and B into C, and C into D. The middle change of B into C might be a 'rayless' change, but it would still be possible to detect it so long as detectable radiation were expelled from A and C. The same point may be illustrated also by a slightly different case taken from an investigation four years ago in a series where some of the changes only emit α rays, and others both α and β rays. If some of the radium emanation which emits α rays, but not β rays, is put into a vessel with thin walls, capable of absorbing completely the α radiation and allowing the β radiation to pass through, no external radiation can be detected from the vessel when the emanation is first introduced. Little by little, as the emanation begins to change, an external radiation comes from the vessel and gradually grows. If now the emanation is blown out of the vessel, the products of its change, being solid, are left behind, deposited on the inside walls. The external radiation is not at first affected, but as time goes on gradually decays away. It would not have made any difference to the above experiment if the emanation had not given out rays. Its existence could have been inferred from its producing a body which did give out rays, and, moreover, the rate of its change into this body could be determined. In this way Rutherford has established that changes occur without the emission of a detectable amount of energy, but which are, nevertheless, demonstrable, because they are preceded and followed by changes in which detectable energy is given out.

In the next place, the past two years' work on the nature of the α ray has shown clearly that it is only detectable within somewhat narrow limits of velocity. If we represent the velocity of the fastest moving α particle expelled from radium by 100, then it has been shown that an α particle moving with a velocity below 43 would fail to be detected by all our methods—electrical, photographic, or phosphorescent. The identical α particle, we know through radioactive tests, might be expelled with a velocity up to 6,000 miles a second, and we should be unaware of it and incapable of detecting it by its energy.

Lastly, the possibility remains to be considered that such a particle might be detectable by its charge. I need only mention the ingenious contrivance of Strutt, popularly known as the radium clock, to illustrate a possible method. This detects the loss by radium of negative electricity carried away by the β particles which are negatively charged. In the same way it might be thought that an otherwise undetectable α radiation might be detected by the loss of positive electricity. This hope, however, proves illusory. There are theoretical grounds which made me suspect that the positive charge carried by the α particle is an accident of the conditions under which it is investigated, and that the α particle is not charged when initially expelled from the atom. This I have now proved to be the case, and, so far as we can see, if its energy was below that at which it could be detected the α particle would never become charged at all.

So that unless entirely new methods of investigation are discovered we are forced back in the search for direct evidence of other processes of evolution on the purely material methods, such as the use of the

spectroscope. Large quantities of materials are required ; these materials are the more likely to be changing the rarer they are, which makes the research very costly, and, in the end, it is by no means certain that a single lifetime is long enough to give to the investigation to secure a positive result. In this connection the suggestion made by our President, Principal Griffiths, is most welcome. If we do not live long enough for the purpose ourselves, it is, as he remarked, our duty to provide our successors with data on which to base their conclusions.

A possible research along these lines, which I started a year ago, but have not yet pushed very far owing to lack of time and material, is the examination of old coins, medals, and ornaments of undoubted antiquity, for evidence of occluded helium or similar gases. The age or date of manufacture of such articles can often be accurately fixed by the expert, and there is a tolerable certainty that the metals were melted during manufacture, and have not been heated since. It seemed that if helium or other gas were found a definite idea of the magnitude of the rate of change might be arrived at, as a preliminary to more direct experiments. But a good deal of material is required, which, however, need not necessarily have any great antiquarian value, so long as its antiquity is above suspicion. An application for help to the British Museum failed, although individual officials have assisted me in the most generous manner from their own collections. But certainly the line of work looks promising enough to justify an attempt if the requisite quantity of material was forthcoming. In the meantime, I have been engaged in a determination of the minimum quantity of helium detectable by the spectroscope, and with some new methods find I can be sure of $\frac{1}{2000}$ th part of a cubic millimetre. This is by far the smallest quantity of any element that has with certainty been detected with the spectroscope.

Taking the possible methods in the order of their directness and certainty, we come next to the method, to which our President has already alluded, by which valuable evidence has been secured to prove that radium is being produced from uranium. If two elements can be shown to occur in constant relative quantity together in all cases in nature, this of itself is the strongest indirect evidence that the one is the parent of the other. If the parent element is the longest lived member of the series, the relative quantities of all the successive members of a disintegration series present with the parent element attain with lapse of time a constant equilibrium value, when as much of each is being formed as disappears in each unit of time. The relative amounts of each member when the equilibrium state is reached is inversely proportional to the relative rates of change, or directly proportional to the average life of each. Thus the researches of Strutt and Boltwood have proved that the amount of radium in all the natural uranium minerals is proportional to the quantity of uranium. This ratio is 1 : 2,500,000, and represents the ratio of the life of radium to that of uranium.

The importance of this result is that it is not confined to radioactive changes. It is a simple deduction which holds good in any series of successive changes where the first change is the slowest and each member changes into the next at a rate proportional to its quantity. If the rate of change of any member is rapid, the equilibrium amount that can accumulate is small ; if the rate of change is slow it will be large. Thus polonium, which is formed from radium, has never yet been obtained in quantities greater than the fraction of a milligram, although many tons of

pitchblende have been worked up for it. Half of it changes in 143 days, which is more than a thousand times faster than radium. Hence the activity is of the order of a thousand times greater, but correspondingly the quantity in pitchblende is of the order of a thousand times less than in the case of radium.

No other cases except those mentioned of two elements always occurring together in constant ratio in nature have as yet been proved, but if this is done it is, as stated, almost sufficient to prove that the rarer element has been formed from the one present in greater abundance, and is itself changing further into some other constituent of the natural mineral.

It remains to point out the limitations of this argument. No equilibrium state can be reached if the parent element is not the most stable of the series. If, for example, thorium were being produced from uranium, there could be no constant ratio between the quantities of uranium and thorium, for the rate of change of the thorium is five times slower than that of uranium, according to a recent accurate determination of Brigg. This indicates that thorium is not a member of the uranium-radium series, for in this case there would exist no proportionality between the uranium and the radium, although there would be between the thorium and radium. The limitation serves to show that the case is likely to be rare if the instability of the radio-elements, as is commonly supposed, is in some way connected with their heavy atomic weight.

We are thus led to consider constancy of association in nature apart from a constant ratio of quantity. This, it will be remembered, gave the necessary clue indicating helium as a disintegration product of radium.

These cases are common enough in chemistry, but little can be at present deduced from existing knowledge. Tantalum and niobium are two inseparable companions in nature. Donald Murray has recently directed attention to the companionship of silver and lead in this connection, and examples could be multiplied. We are still in darkness as to whether there is any process complementary to disintegration, simultaneously building up the elements of heavier atomic weight and maintaining their quantity, and this constant association in nature could result as well from a simultaneous formation of both elements or from the building up of one from the other. Without other evidence no certain conclusion can yet be drawn in this field.¹

A slightly different phase of the same question is seen in an element having an approximate constant rarity in nature after prolonged and extensive search for it. I have drawn attention to the fact that the coinage metals, in particular gold, silver and platinum, of necessity fulfil this condition more or less completely, indicating that these metals are likely subjects for a direct examination for evidence of slow changes. I have referred to the case of coins, where for practical reasons a direct examination is probably more likely to yield fruit than in any other case.

So far as the economic evidence goes, the scarcity of gold is a matter of concentration, like that of radium, for in small quantities it is, like radium, very widely distributed. Seeing that 500 tons of gold were produced

¹ In the writer's opinion Mr. Strutt's remarkable results, showing that the quantity of radium in the common rocks of the earth's crust is so great that a crust composed of these rocks only a few miles thick would supply the heat lost by the earth and maintain it at constant temperature, seem to suggest the first experimental indication that there is actually taking place a process of atomic upbuilding with the necessarily enormous absorption of energy.

last year, the element can hardly be considered scarce in any other sense of the word. It has the remarkable property of being found just whenever the demand for it increases, and the providential character of this behaviour makes me suspect that a law similar to that regulating the scarcity of radium is in question. If this turns out to be well founded, the theory of currency will be reduced to a branch of physics. We may anticipate a more scientific system of currency being devised than the present, which in 1904 cost the world from fifty to a hundred million pounds value thrown away in the unproductive labour of maintaining the gold and silver currency.

So far only what may be termed passive lines of investigation have been considered where processes of spontaneous evolution are supposed to be taking place. There is no evidence whatever that any of the known processes can be in any way artificially influenced. If such were possible it would be tantamount to an artificial transmutation. But at least we know the lines along which even this more ambitious attempt might have a chance of success. The matter in question should be as minute in quantity, and the energy acting upon it as intense, as possible. These conditions are realised in the case of the residue of gas left in an X-ray bulb through which large amounts of electrical energy of great intensity are passed. The idea has long been held that possibly in these bulbs the disappearance of the gas with use, resulting in the gradual improvement of the vacuum so well known to the X-ray operator, may be due to a real transmutation or resolution of the gas under the drastic treatment to which it is exposed. But no experiments have been published, so far as I am aware, along these lines, and the whole subject has not yet advanced beyond the speculative stage.

It remains to be seen whether the lines of investigation here sketched will bear fruit. With the problem of artificial transmutation is linked that of the ultimate utilisation of the internal energy of elements, the solution of which would change our destiny. The importance of the problem cannot be questioned, but its magnitude is reflected in the difficulties which beset its investigation. To control natural phenomena we must first learn how to imitate them, and this is only possible when an intimate knowledge of the underlying laws has been attained. It may well be that the single life of the individual and the limited resources at his command must be replaced by an organised assault on the part of institutions equipped for the purpose where continuity of purpose can be secured and experiments on a large scale performed.

Magnetic Survey of South Africa.—Preliminary Report of the Committee, consisting of Sir DAVID GILL (Chairman), Professor J. C. BEATTIE (Secretary), Mr. S. S. HOUGH, Professor MORRISON, and Professor A. SCHUSTER, appointed to continue the Magnetic Survey of South Africa commenced by Professors Beattie and Morrison.

OBSERVATIONS were taken at twenty-two stations in the Transkei, and at three stations in Bechuanaland. The observations at Mafeking, one of the Bechuanaland stations, extended over four days, and the results

furnish important information on the secular variation of the elements at this place. The other twenty-four stations were occupied for the first time.

The various astronomical and magnetic reductions have been carried out twice, and the results have been reduced to the epoch July 1, 1903. Maps have been prepared showing the isomagnetics in the Transkei; and at present the magnetic anomalies for that region are being calculated.

The Committee ask for reappointment, with a grant of 50%, for the purpose of carrying the survey into Little Namaqualand. The Government of Cape Colony has placed 100% on the estimates for the incoming year for the same purpose.

Report on Results of Magnetic Observations in the Transkei and in Bechuanaland. By J. C. BEATTIE, D.Sc., Professor of Physics, South African College, Cape Town.

The observations in the Transkei were made by Professor Morrison, assisted by Professor Brown; the instruments used were a Kew magnetometer, No. 31, by Elliott, and a dip circle, No. 9, by Dover. For

TABLE I.

Station	Date	G.M.T.	Declination	Latitude	Longitude	No.
1906.						
		H. M.	°	'	°	'
Imvani	Jan. 9	6 54 a.m.	25 41.1 W.	32 2.0 S.	27 5.0 E.	1
Toise River	" 10	6 31 "	26 5.5 "	32 27.0 "	27 28.7 "	2
Amabele Junction	" 11	6 8 "	25 40.0 "	32 43.1 "	27 19.2 "	3
Komgha	" 13	3 37 p.m.	25 45.8 "	32 35.6 "	27 54.5 "	4
East of Komgha	" 14	5 44 a.m.	25 44.2 "	32 32.6 "	27 58.3 "	5
Butterworth Road	" 15	6 0 "	25 27.9 "	32 21.3 "	28 4.0 "	6
Between Butterworth and Idutywa	" 16	6 12 "	25 33.8 "	32 13.4 "	28 10.4 "	7
East of Idutywa	" 17	8 5 "	25 33.1 "	32 0.8 "	28 20.4 "	8
Near Bashee	" 18	6 58 "	25 35.3 "	31 42.0 "	28 30.4 "	9
Umтата	" 20	6 28 "	24 49.2 "	31 35.9 "	28 47.1 "	10
Libode	" 21	5 35 "	24 49.6 "	31 32.1 "	29 1.5 "	11
	" 22	6 16 "	24 47.2 "	31 36.0 "	29 19.6 "	12
Port St. John's	" 23	6 42 "	24 54.9 "	31 37.8 "	29 33.0 "	13
Amaranya	" 26	—	—	31 14.7 "	29 30.0 "	15
	" 27	10 25 "	23 52.2 "	31 0.6 "	29 30.5 "	16
Near Mount Ayliff	" 28	8 28 "	24 9.5 "	30 48.2 "	29 31.5 "	17
	" 29	1 56 p.m.	23 47.1 "	30 49.7 "	29 15.5 "	18
Mount Frere	" 30	9 26 a.m.	24 8.8 "	30 53.5 "	28 59.0 "	19
Tsolo	Feb. 3	7 7 "	24 26.1 "	31 18.2 "	28 45.6 "	21
Near Ugie	" 5	6 46 "	24 43.9 "	31 8.0 "	28 26.2 "	22
Elliott	" 6	6 0 "	24 31.0 "	31 18.0 "	27 54.0 "	23
Mafeking	Jan. 24	7 48 "	22 43.8 "	25 52.0 "	25 39.0 "	24
"	" 24	10 21 "	22 35.9 "	" "	" "	"
"	" 24	12 27 "	22 34.1 "	" "	" "	"
"	" 24	2 37 p.m.	22 36.0 "	" "	" "	"
"	" 25	8 5 a.m.	22 44.4 "	" "	" "	"
"	" 25	10 32 "	22 40.1 "	" "	" "	"
"	" 25	12 54 p.m.	22 35.8 "	" "	" "	"
Maribogo	" 27	2 36 "	23 6.1 "	26 25.1 "	25 10.0 "	25
"	" 28	7 52 a.m.	23 15.7 "	" "	" "	"
"	" 28	10 22 "	23 7.8 "	" "	" "	"
Vryburg	" 29	1 37 p.m.	22 27.2 "	26 57.1 "	24 43.0 "	26
"	" 29	3 8 "	22 30.4 "	" "	" "	"
"	" 30	7 27 a.m.	22 37.2 "	" "	" "	"
"	" 30	9 44 "	22 30.8 "	" "	" "	"

astronomical determinations a 5-inch theodolite and a chronometer, which was rated telegraphically about twice a week, were carried.

In the three stations occupied in Bechuanaland the observations were made by the writer, who used a Kew magnetometer, No. 73, by Elliott, on loan from the Royal Society, London ; a dip circle, No. 142, by Dover ; a 5-inch theodolite, and a chronometer.

The method of taking the observations was the same as in the other observations in connection with the magnetic survey of South Africa. A full account of it will be found in the report of that survey by the writer, to be published by the Royal Society.

The instruments 31 and 73 differ in the declination and in the horizontal intensity by 2'0 and 20γ respectively. The dip circles agree with each other.

Table I. contains the observed values of declination.

The values of the declination were next corrected for daily variation, and then reduced to July 1, 1903. No correction for daily variation was applied to either the horizontal intensity or to the dip. Both were reduced to epoch July 1, 1903.

The reduced values were used to calculate the total (T), the vertical (Z), the northerly (X), and the westerly (Y) components of the intensity.

The results are given in Table III.

TABLE II.

Observed Values of Horizontal Intensity (H) and of dip (I).

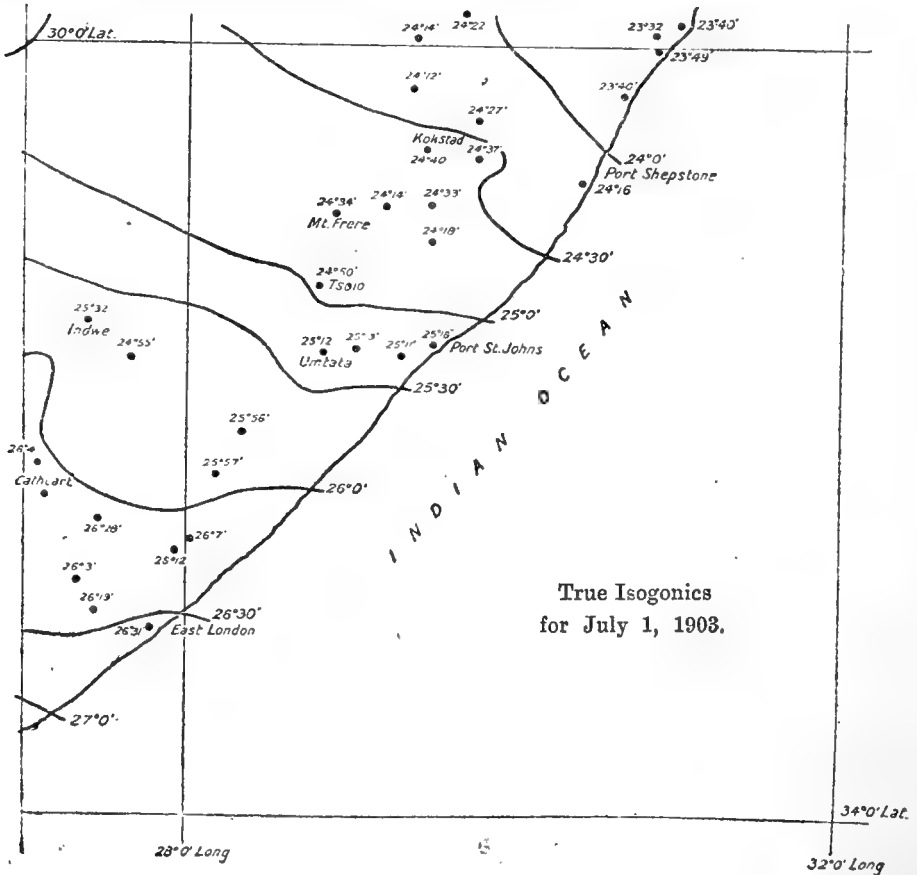
Place	Date	G.M.T.	H.	G.M.T.	θ	Latitude	Longitude	No.
1906.								
			H. M.	C.G.S.	H. M.	S.	S.	E.
Imvani	Jan. 9	9 46 a.m.	'17539	2 48 p.m.	61 48'1	—	—	1
Toise River	" 10	9 1 "	'17317	10 52 a.m.	62 7'0	—	—	2
Amabele Junction	" 11	8 23 "	'17572	9 59 "	61 42'3	—	—	3
Komgha	" 13	8 36 "	'17539	10 32 "	61 55'2	—	—	4
East of Komgha	" 14	8 10 "	'17487	9 46 "	61 52'9	—	—	5
Butterworth Road	" 15	7 58 "	'17597	9 36 "	61 40'4	—	—	6
Between Butterworth and Idutywa	" 16	8 26 "	'17559	10 12 "	61 39'1	—	—	7
East of Idutywa	" 17	10 43 "	'17312	2 10 p.m.	62 4'5	—	—	8
Near Bashee	" 18	9 47 "	'17542	11 45 a.m.	61 55'5	—	—	9
Umtata	" 20	9 14 "	'17634	3 10 p.m.	61 55'8	—	—	10
Libode	" 21	8 24 "	'17761	10 26 a.m.	61 51'5	—	—	11
Umhlangana Pass	" 22	8 51 "	'17542	10 39 "	62 10'7	—	—	12
Port St. John's	" 23	9 30 "	'17301	11 6 "	62 22'1	—	—	13
	" 25	8 57 "	'18203	2 59 p.m.	61 22'7	31 26'0	29 31'0	14
Amaranya	" 26	9 45 "	'17826	4 16 p.m.	61 20'9	—	—	15
	" 27	12 12 p.m.	'17725	9 28 a.m.	61 27'5	—	—	16
Near Mount Ayliff	" 28	10 26 a.m.	'17642	12 2 p.m.	61 37'1	—	—	17
	" 29	10 14 "	'17705	11 58 a.m.	61 38'5	—	—	18
Mount Frere	" 30	10 39 "	'17819	12 55 p.m.	61 22'3	—	—	19
	" 31	11 6 "	'17545	9 38 a.m.	61 40'1	30 59'0	28 51'0	20
Tsolo	Feb. 3	9 38 "	'17753	11 19 "	61 18'0	—	—	21
Near Ugie	" 5	8 54 "	'17721	10 27 "	61 32'7	—	—	22
Elliott	" 7	9 0 "	'17748	10 31 "	61 25'5	—	—	23
Mafeking	Jan. 24	9 20 "	'19322	—	—	—	—	24
"	" 24	1 37 p.m.	'19289	—	—	—	—	
"	" 25	8 33 a.m.	'19301	—	—	—	—	
"	" 26	9 35 "	'19322	8 48 "	57 14'1	—	—	
Maribogo	" 27	12 40 "	'19188	—	—	—	—	25
"	" 28	9 10 "	'19189	9 20 "	57 38'3	—	—	
Vryburg	" 29	9 37 "	'18993	—	—	—	—	26
"	" 30	8 39 "	'19019	8 42 "	53 21'8	—	—	

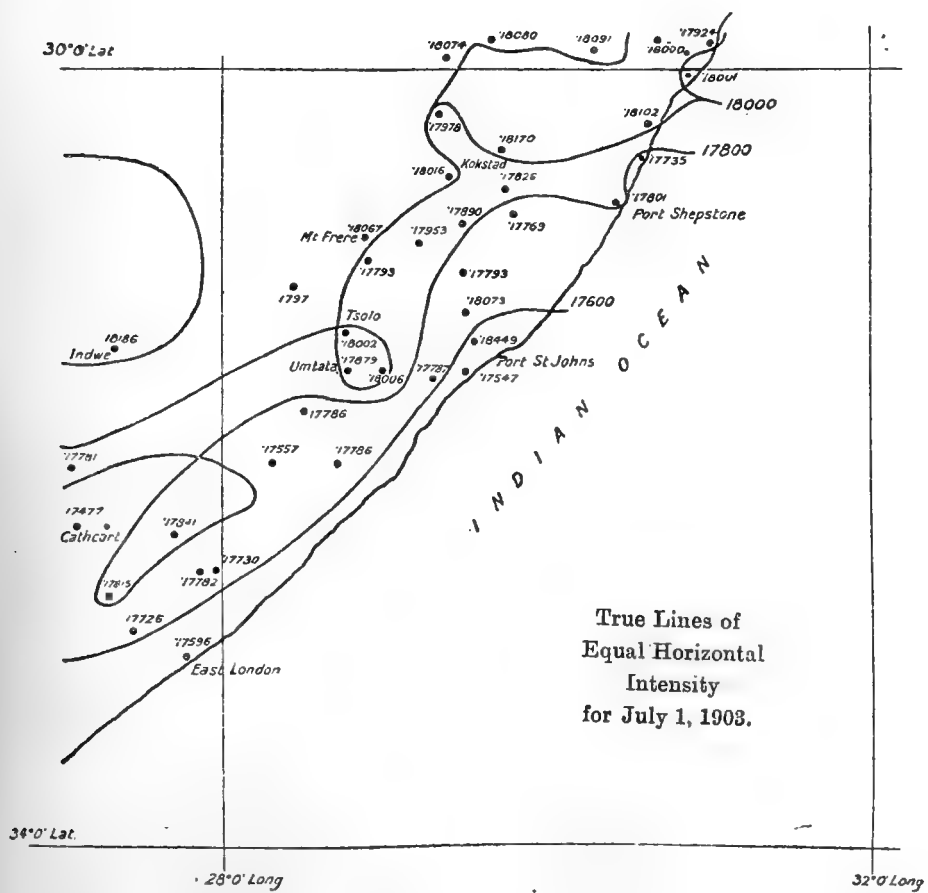
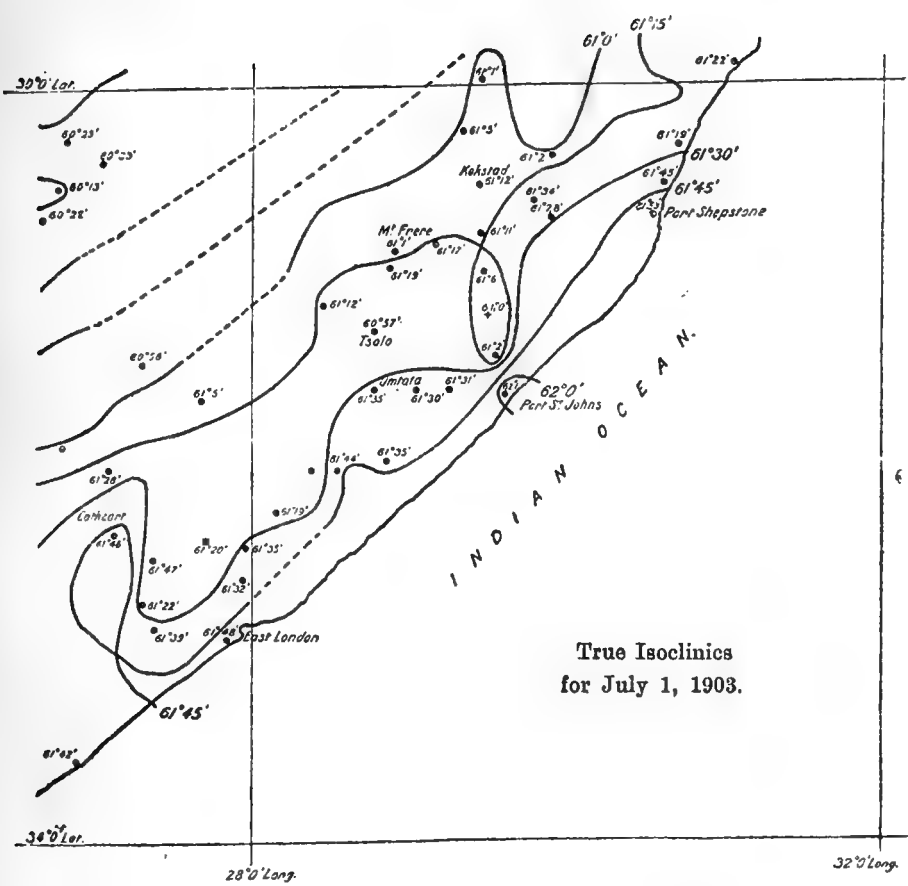
TABLE III.

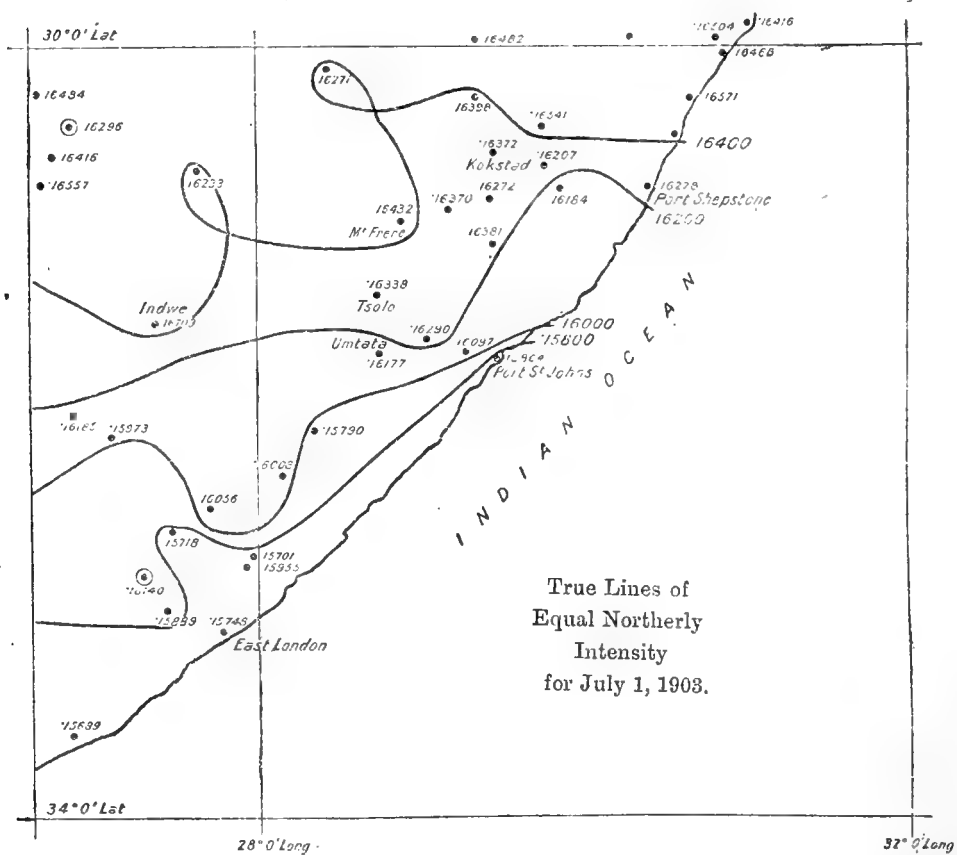
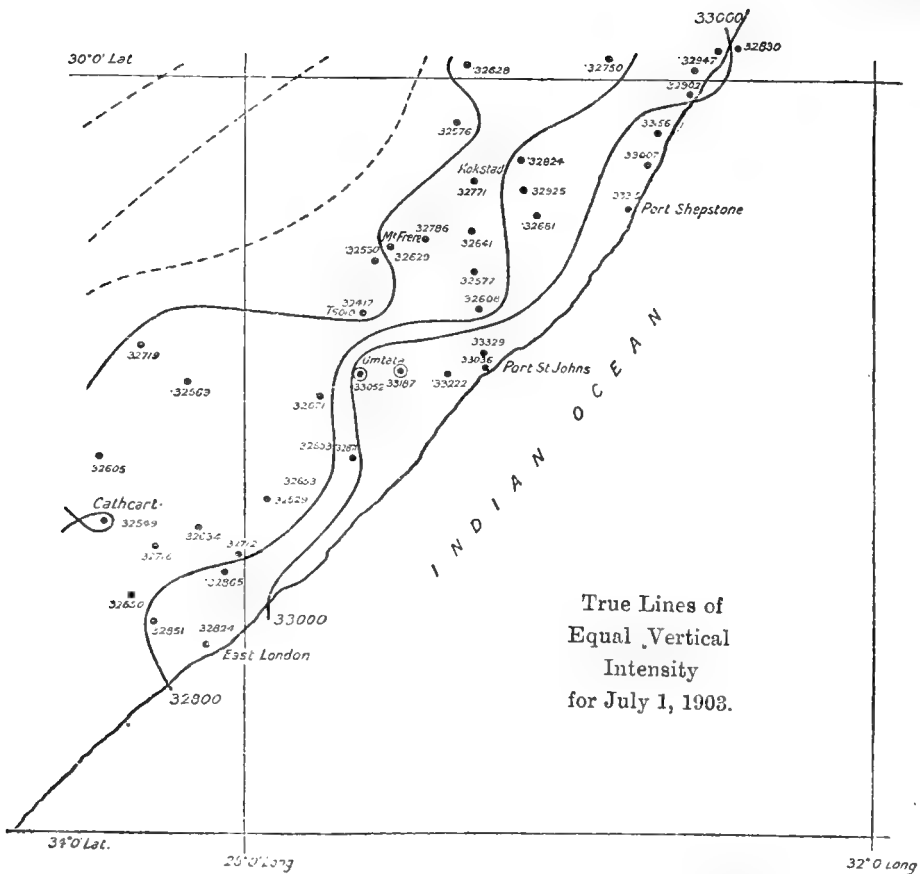
Values of the Magnetic Elements reduced to July 1, 1903.

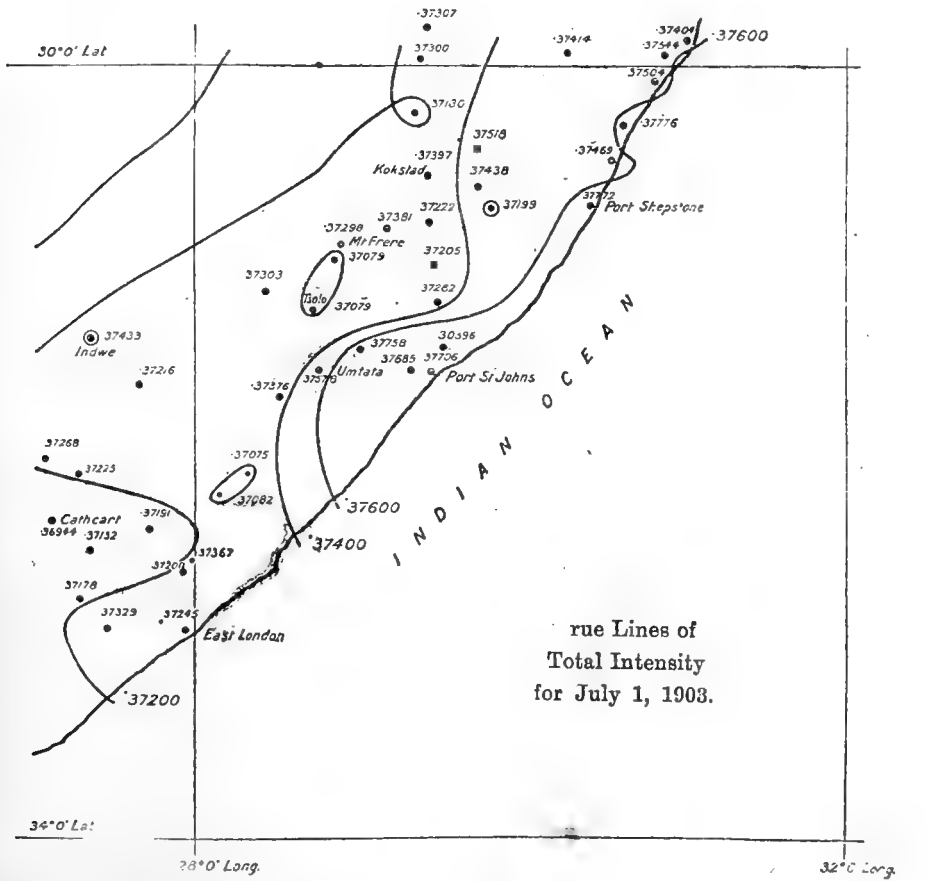
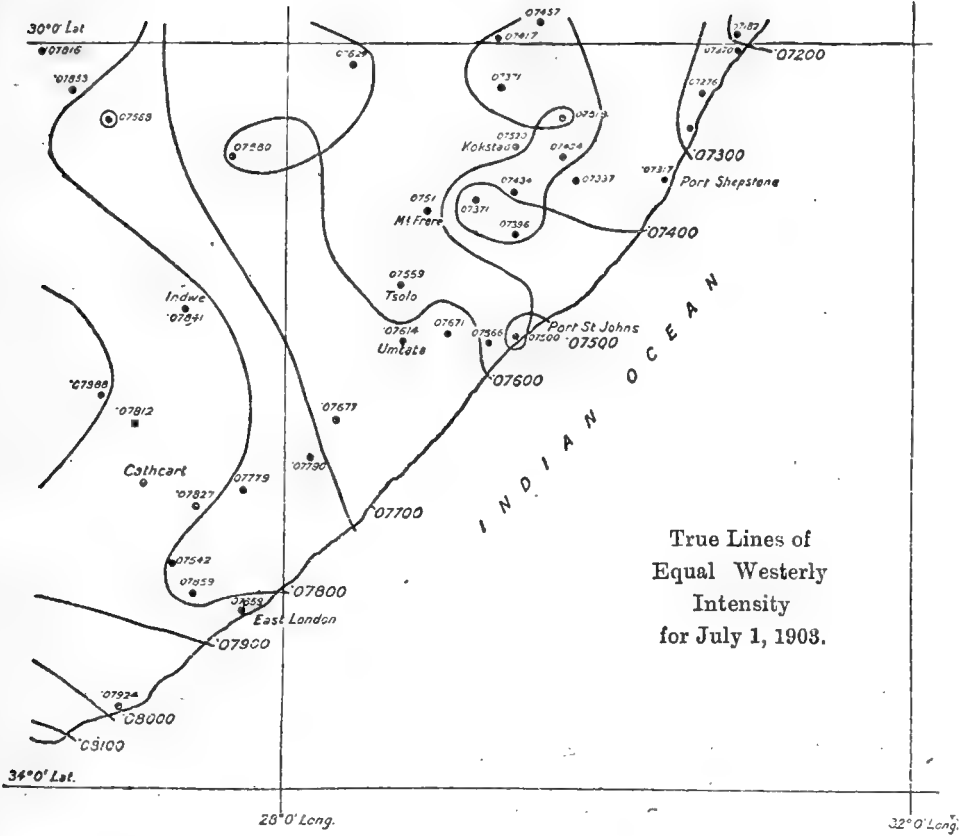
No.	Declination (D)	H	θ	T	Z	X	Y
		C.G.S.	$^{\circ}$	C.G.S.	C.G.S.	C.G.S.	C.G.S.
1	26 3'7 W.	-17781	61 28'0 S.	-37225	-32699	-15973	-07812
2	26 28'2 "	-17559	61 46'7 "	-37132	-32716	-15718	-07827
3	26 2'9 "	-17815	61 22'1 "	-37178	-32630	-16140	-07542
4	26 12'0 "	-17782	61 35'0 "	-37367	-32865	-15955	-07851
5	26 7'2 "	-17730	61 32'6 "	-37209	-32712	-16701	-07589
6	25 51'1 "	-17841	61 20'1 "	-37191	-32634	-16056	-07779
7	25 56'8 "	-17803	61 18'7 "	-37078	-32529	-16008	-07790
8	25 55'8 "	-17657	61 44'1 "	-37075	-32653	-15790	-07677
9	25 58'4 "	-17786	61 35'1 "	-37376	-32871	-15990	-07789
10	25 12'3 "	-17879	61 35'4 "	-37578	-33052	-16177	-07614
11	25 13'0 "	-18006	61 31'1 "	-37758	-33187	-16290	-07671
12	25 10'5 "	-17787	61 50'2 "	-37685	-33222	-16097	-07566
13	25 18'2 "	-17547	62 1'5 "	-37406	-33036	-15864	-07500
14	—	-18449	61 2'1 "	-38096	-33329	—	—
15	—	-18073	61 0'2 "	-37282	-32608	—	—
16	24 17'9 "	-17973	61 6'8 "	-37205	-32577	-16381	-07396
17	24 33'1 "	-17890	61 16'4 "	-37222	-32641	-16272	-07434
18	24 14'4 "	-17953	61 17'8 "	-37381	-32786	-16370	-07371
19	24 33'6 "	-18067	61 1'6 "	-37298	-32629	-16432	-07510
20	—	-17793	61 19'4 "	-37079	-32530	—	—
21	24 49'6 "	-18002	60 57'3 "	-37079	-32417	-16338	-07559
22	25 7'3 "	-17971	61 12'0 "	-37303	-32690	-16271	-07629
23	24 54'7 "	-17998	61 4'7 "	-37216	-32569	-16233	-07580
24	23 4'4 "	-19487	57 14'1 "	-36008	-30277	-17927	-07640
25	23 35'4 "	-19366	57 18'6 "	-35857	-30176	-17748	-07750
26	22 57'5 "	-19179	58 2'3 "	-36230	-30737	-17660	-07481

The maps following are drawn from the above data.









Investigation of the Upper Atmosphere by Means of Kites in co-operation with a Committee of the Royal Meteorological Society.—Fifth Report of the Committee, consisting of Dr. W. N. SHAW (Chairman), Mr. W. H. DINES (Secretary), Mr. D. ARCHIBALD, Mr. C. VERNON BOYS, Dr. A. BUCHAN, Dr. R. T. GLAZEBROOK, Dr. H. R. MILL, Professor A. SCHUSTER, and Dr. W. WATSON. (Drawn up by the Secretary.)

SINCE the date of sending in the last report an investigation into the conditions prevailing over the North Sea has been carried on by Mr. G. C. Simpson, who kindly undertook the work at the request of the Joint Committee. Mr. Simpson spent three weeks on the North Sea in the mission ship 'Alexandra,' which was attached to the Red Cross Trawling Fleet. The results he obtained have been published in the 'Quarterly Journal of the R. Met. Soc.,' vol. xxxii., No. 137.

Observations were also continued at Oxshott, on behalf of the Joint Committee, down to the end of September 1905, and the results of these observations, together with those previously obtained at Crinan and at Oxshott, have been published in the 'Proceedings of the Royal Society,' A, vol. lxxvii. 1906.

Since October 1, 1905, the work of obtaining systematic observations has been undertaken by the Meteorological Office, whose station is at present situated at Oxshott; but Mr. Simpson is arranging a kite station on the moors near Manchester, at which it is hoped that kite ascents can be made on suitable days, and more particularly on the days appointed by the International Committee.

The Committee ask for reappointment, and for a grant of 25*l.*

The Distribution of Prussic Acid in the Vegetable Kingdom.
By MAURITS GRESHOFF, Ph.D.

[Ordered by the General Committee to be printed *in extenso*.]

THE President of the Chemical Section has honoured me with an invitation to give a paper on cyanogenesis, that very important phyto-chemical problem in which I have taken an interest ever since I went to Buitenzorg, now eighteen years ago. I began my work on the distribution of prussic acid among plants with *Pangium edule*. In recent years I have had, owing to the pressure of other work, to relinquish investigation in this direction, and I am now scarcely more than a spectator of the progress made from year to year.

The following list shows concisely our present knowledge of the extent to which prussic acid occurs in plants:—

DICOTYL. POLYPETAL. Fam. 1—90.

Fam. 1. Ranunculaceæ.

Aquilegia vulgaris (—, Jorissen 1884), *A. chrysantha* (*n.B.*, Greshoff 1906).

Thalictrum aquilegifolium (*A.*, v. Itallie 1905).

- Fam. 7. Berberidaceæ.
Nandina domestica (A., Dekker 1906).
- Fam. 12. Cruciferæ.
Lepidium sativum (—, Schulze 1860).
- Fam. 18. Bixaceæ (A.).
 subf. Pangieæ ('Hydrocyaniferæ').
Gynocardia odorata (Greshoff 1890).
Hydnocarpus venenata v. *inebrians*, *H. alpina* (Greshoff 1890), *H. anthelmintica* (Power 1905).
Kiggelaria africana (Wefers Bettink 1891).
Pangium edule, *P. ceramense* (Greshoff 1889).
Ryparosa cæsia, *R. longipedunculata* (Greshoff 1891).
Taraktogenos Blumei (Greshoff 1892), *T. Kurzii* (Power 1904).
Trichadenia zeylanica (Greshoff 1890).
- Fam. 34. Sterculiaceæ.
Sterculia (*Pterocymbium*) sp. (*n.B.*, v. Romburgh 1897).
- Fam. 35. Tiliaceæ.
Echinocarpus (*Sloanea*) *Sigun* (*B.*, Greshoff 1892).
- Fam. 36. Linaceæ.
Linum usitatissimum, *L. perenne* (A., Jorissen 1884).
- Fam. 41. Rutaceæ.
 ? *Citrus medica*.
- Fam. 46. Dichopetalaceæ.
Chailletia cymosa (Dunstan 1903).
- Fam. 47. Olaceaceæ.
Ximenia americana (*B.*, Ernst 1887), *X. elliptica* (*B.*).
- Fam. 50. Celastraceæ.
Kurrimia zeylanica (*n.B.*, v. Romburgh 1897).
- Fam. 53. Rhamnaceæ.
Rhamnus Frangula (—, Lehmann 1874).
- Fam. 55. Sapindaceæ.
Cupania sp. (*n.B.*, v. Romburgh 1897).
Schleichera trijuga (*B.*, Thümmel 1889).
- Fam. 61. Anacardiaceæ.
Corynocarpus lævigata (*B.*, Easterfield 1903).
- Fam. 65. Leguminosæ-Papilionaceæ.
Lotus arabicus, *L. australis* (*L.*, Dunstan-Henry 1900).
Indigofera galegoides (*B.*, v. Romburgh 1893).
Phaseolus lunatus (A., Davidson 1884).
Vicia sativa (*B.*, Ritthausen 1870), *V. angustifolia*, *V. hirsuta* (—, Bruyn-
 ing- v. d. Harst 1899), *V. macrocarpa* (—, Guignard 1906).
Dolichos Lablab (Leather 1906).
- Fam. 66. Rosaceæ (? *B.*).
 subf. Pomoideæ.
Amelanchier vulgaris (Wicke 1851), *A. canadensis*, *A. alnifolia* (Greshoff 1896).
Chamæmeles sp.
Cotoneaster integerrima (Wicke 1851), *C. microphylla* (Greshoff 1906).
Cratægus Oxyacantha (Wicke 1851), *C. orientalis* (Greshoff 1896).
Eriobotrya japonica (Wicke 1851).
Nuttallia cerasiformis.
Osteomeles sp.
Photinia (*Heteromeles*) *arbutifolia* (Lustig 1882).
Pyrus (*Cydonia*, *Malus*, *Mespilus*, *Sorbus*), sp. div. : *P. Aria*, *P. Aucuparia*,
P. Cydonia, *P. japonica*, *P. Malus*, *P. Mespilus*, *P. pinnatifida*, *P. terminalis* (± 1850), *P. spectabilis*, *P. Ringo* (Greshoff 1896).
 subf. Prunoideæ.
Prunus Amygdalus, *P. Laurocerasus* (Schrader 1803), *P. armeniaca*, *P. persica* (Vauquelin 1803), *P. Padus* (Bergemann 1812), *P. avium*, *P. Cerasus*, *P. domestica*, *P. insititia*, *P. occidentalis*, *P. pennsylvanica*, *P. spinosa*, *P. undulata* (± 1850), *P. scrotina* (Perot 1852), *P. lusitanica* (Flückiger 1879), *P. virginiana* (Schimmel 1890), *P. alleghaniensis*, *P. Bessiei*, *P. divaricata*, *P. paniculata*, *P. pendula* (Greshoff 1896), *P. subhirtella* (v. d. Ven 1898), *P. adenopoda*, *P. javanica* (v. Romburgh 1898).

- Fam. 66. *Pygeum africanum* (Welwitsch 1860), *P. parviflorum*, *P. latifolium* (Greshoff 1890).
 subf. *Spirææ*.
Spiræa Aruncus, *S. sorbifolia*, *S. japonica* (Wicke 1851), *S. Kneiffii* (Greshoff 1906).
- Fam. 67. *Saxifragaceæ*.
Ribes aureum (—, Jorissen 1884), *R. nigrum*, *R. rubrum* (—, Hébert-Heim 1897), *R. Grossularia* (—, Guignard 1905).
- Fam. 74. *Combretaceæ*.
 ? *Combretum constrictum*. (? *B.*)
- Fam. 75. *Myrtaceæ*.
 ? *Psidium montanum*. (? *B.*)
- Fam. 76. *Melastomaceæ*.
Memecylon sp. div. (*B.*, v. Romburgh 1899).
- Fam. 79. *Samydaceæ*.
Homalium (*Blackwellia*) sp. div. (*B.*, v. Romburgh 1899).
- Fam. 82. *Passifloraceæ*.
Passiflora quadrangularis, *P. laurifolia*, *P. princeps* (*n.B.*, v. Romburgh 1897), *P. cærulea* (*A.*, Dekker 1906).
Tacsonia sp. (*n.B.*, v. Romburgh 1898), *T.* var. *Volxmii* (Dekker 1906).

DICOTYL. GAMOPET. Fam. 91—136.

- Fam. 91. *Caprifoliaceæ*.
Sambucus nigra (*B.*, Bourquelot-Guignard 1905).
- Fam. 92. *Rubiaceæ*.
Plectronia dicocca (*B.*, v. Romburgh 1898).
- Fam. 96. *Compositæ*.
Chardinia xeranthemoides (*B.*, Eichler 1862).
Xeranthemum annuum, *X. cylindraceum* (*B.*, Greshoff 1899).
- Fam. 100. *Sapotaceæ*.
 ? *Isonandra* (*Bassia*) *mottleyana* (? *B.*).
Lucuma bonplandia (*B.*, Altamirano 1876), *L. mammosa* (*B.*).
 ? *Payena latifolia* (? *B.*).
- Fam. 116. *Asclepiadaceæ*.
Gymnema latifolium (*B.*, Greshoff 1890).
- Fam. 122. *Convolvulaceæ*.
Ipomœa dissecta (*B.*, Prestoe 1874), *I. sinuata* (*B.*, v. Romburgh 1894).
T. (*Merremia*) *vitifolia* (*B.*, Weehuizen 1906).
- Fam. 129. *Bignoniaceæ*.
 ? *Osmohydrophora nocturna* (? *B.*).

DICOTYL. MONOCHLAMYD. Fam. 137—172.

- Fam. 160. *Euphorbiaceæ*.
Bridelia ovata (—, v. Romburgh 1899).
Elateriospermum Tapos (—, v. Romburgh 1899).
Hevea brasiliensis, *H. spruceana* (*A.*, v. Romburgh 1893).
Jatropha angustidens (*A.*, Heyl 1902).
Manihot utilisima, *M. palmata* (*A.*, Henry 1830), *M. bankensis*, *M. Glaziovii* (*A.*, Greshoff 1892).
Ricinus communis (—, Ritthausen 1870).
- Fam. 162. *Urticaceæ*.
Sponia virgata (—, v. Romburgh 1899).

MONOCOTYL. Fam. 173—207.

- Fam. 198. *Araceæ*.
Arum maculatum (*n.B.*, Jorissen 1884).
Colocasia gigantea (*n.B.*, v. Romburgh 1897).
Cyrtosperma lasioides, *C. Merkusii* (*n.B.*, Greshoff 1890).
Lasia aculeata, *L. Zollingeri* (*n.B.*, Greshoff 1890).

Fam. 207. Gramineæ.

- Glyceria aquatica* (—, Jorissen 1884).
Panicum sp. div. (*B.*, Brünnich 1903).
Sorghum vulgare (*B.*.*, Dunstan-Henry 1902).
Stipa hystricina, *S. leptostachya* (—, Hébert-Heim 1904).

GYMNOSPERMÆ. Fam. 208—210.

CRYPTOGAMÆ. Fam. 211— .

Fungi.

- ? *Hygrophorus agathosmus*, *H. cerasinus* (? *B.*).
Marasmius oreades (*B.*, Loesecke 1871).
 ? *Pholiota radicata* (? *B.*).
 ? *Russula foetens* (? *B.*).

The length of this list shows in a surprising manner that prussic acid, a compound formerly supposed to occur only in the bitter almond, the cherry laurel, and some related plants, seems to be distributed in widely different natural orders. The dates given in the list indicate clearly that our knowledge of this distribution is mainly of recent acquisition. This is still more clearly shown if we consider only the cyanogenetic glucosides so far isolated and either partially or fully investigated.

1830. Amygdalin (Robiquet and Boutron-Charlard).
 1891. Linamarin, now known to be identical with phaseolunatin (Dunstan Henry and Auld ¹) (Jorissen and Hairs).
 1901. Lotusin (Dunstan and Henry).
 1902. Dhurrin (Dunstan and Henry).
 1903. Phaseolunatin (Dunstan and Henry).
 1903. Corynocarpin (Easterfield and Aston).
 1904. Gynocardin (Power and Lees).
 1905. Sambunigrin (Bourquelot and Danjou).
 1905. Prulaurasin (Herissey).

The complete investigation of several of these cyanogenetic glucosides has greatly enlarged our insight into the ways in which prussic acid is combined in the plant. It is with pleasure I take this opportunity of paying homage to these English researches so highly appreciated by scientists throughout the world.

This paper would become unduly long if I dwelt on every case of cyanogenesis, with several of which I occupied myself personally. As an instance of the difficulties attending the work may be mentioned a controversy which arose over a single plant (*Arum maculatum*). The Belgian chemist Jorissen, to whom we owe some interesting observations regarding the distribution of hydrocyanic acid in plants other than the Rosaceæ, mentioned in 1889 that on distilling *Arum* he found a small quantity of prussic acid in the distillate, but other investigators were unable to confirm this. When later I found prussic acid in some Javanese Araceæ I wrote to Professor Plugge asking him to investigate *Arum maculatum*. He thereupon completely confirmed Jorissen's results.² A short time ago I was informed by the well-known plant physiologist, Dr. Burek, who has long devoted attention to the biology of flowers, that the trace of prussic acid in *Arum* plays a very special part in the biological

¹ *Proc. Roy. Soc.*, 1906, 78, 345.

² Similarly, after much opposition, Jorissen was shown to be right with regard to the production of prussic acid by flax.

process, as it gradually narcotises and kills any insects which may have penetrated into the flower after they have performed their task of bringing about self-fertilisation.

The estimation of the amount of prussic acid yielded by plants is also a matter of importance. In my own work I have followed the plan of crushing the plant under water and then macerating it without acid in a moderate quantity of water to allow the enzyme to break up the whole of the cyanogenetic glucoside. Even when dealing with very small quantities of acid I usually precipitate it at once as cyanide of silver, which, after having being weighed, can still be converted into Prussian blue. I may remark here that sometimes in the investigation of plants which contain but a small quantity of an amygdalin-like glucoside only benzaldehyde is found in the distillate, the hydrocyanic acid being either consumed by the plant or escaping into the air. Thus in *Xeranthemum* I found benzaldehyde repeatedly, but only once hydrocyanic acid. Similarly in some plants, *e.g.* *Gymnema*, the quantity of enzyme present is insufficient to hydrolyse the glucoside; in that case emulsin should be added in the form of sweet-almond emulsion. Treub has shown that in these researches the micro-chemical method of studying the localisation of prussic acid in the plant is of great value. I will give here the *modus operandi*, proposed by me in 1889. Place a freshly cut section, not too thin and containing at least one layer of intact cells, in a 5-per-cent. alcoholic potash solution, then transfer it after 15 to 90 seconds to a warm (60° C.) ferrous-ferric solution (2.5 per cent. ferrous sulphate and 1 per cent. ferric chloride) and leave it there for ten minutes, and finally place it for from five to fifteen minutes in dilute hydrochloric acid (one part of concentrated acid and six parts of water). A section so prepared shows minute agglomerations of Prussian blue wherever prussic acid occurred in the original thin section. In order to follow the distribution in whole leaves these may be uniformly pricked by means of a brush of thin steel needles arranged in rows and then subjected to the reagents mentioned above. Even hard and leathery leaves when pricked in this way receive regularly distributed small holes, through which the reagents can penetrate.

As regards the physiological rôle of prussic acid in plants there is yet no consensus of opinion.

Treub regards the hydrocyanic acid in *Pangium edule* as the first product of nitrogen assimilation in the formation of albuminoid matter. Treub has considerable experience of plant physiology and anatomy, and has built up his theory on experimental results obtained with living *Pangium* plants at Buitenzorg, so that it cannot be refuted by mere discussion. Prussic acid is abundant in the growing parts of this plant; in young foliage there occurs 0.3 per cent. HCN. I estimated the total amount in a single *Pangium* tree at 350 grams.

This remarkable abundance of the acid and the fact that it appears to be produced in special cells of great chemical activity, as is proved by the simultaneous occurrence in them of prussic acid, proteid matter, and calcium oxalate, and the evident influence of sunlight on its formation, the dependence of this formation on the presence of sugar and nitrates in the green leaves in which cyanogenesis occurs, the transport of the prussic acid from leaves along the phloem to the growing parts or to the seeds as a reserve material, have all been fully proved by Treub's investigation. Similarly he studied for some years the physiology of another plant yield-

ing prussic acid, the poisonous variety of *Phaseolus lunatus*. This second series of results indicates that in this plant also prussic acid is a plastic material for proteid synthesis.

Now we may ask, Is this so for every plant and under all circumstances? We may defend the hypothesis, but must acknowledge that we have no proof for it.

During the last twenty years many plants have been examined with a view to ascertaining whether they yield prussic acid. My friend Professor van Romburgh has examined over a thousand species, but only a few of these gave positive results, though 0.001 per cent. of acid can be detected with perfect certainty. Compared with the distribution of other special plant products, e.g. saponin and cumarin, prussic acid is comparatively rare. Sometimes it is absent in plants in which the literature states it to be present, e.g. *Viola* and *Mitchella*.

Those who believe that prussic acid plays an important part in proteid synthesis have their answer ready, and it is worth consideration. The plant, they say, produces the acid, but uses it immediately to produce more complicated compounds. As a proof that the acid can escape detection as an intermediate compound, we may refer to *Phaseolus lunatus*. In the young leaf much free hydrocyanic acid is to be found, and in the ripe seeds there is also much hydrocyanic acid, not free, but combined as a glucoside, which must have been transported from the leaves along the stem. But in the stem itself no prussic acid can be found. Hence it must be acknowledged that the fact of this body not being found is not sufficient proof that it does not play an important part in the life of the plant. Nevertheless it is curious that, as a rule, we cannot find even a trace of the acid with our most sensitive reagents, if at any given moment we analyse the whole plant.

It may be urged, on the other hand, that all plants do not exhibit a prussic-acid stage in the proteid synthesis, and that such a phenomenon is a special feature only in some plants, or in certain groups of plants. But even in the Bixaceæ and the Rosaceæ, hydrocyanic acid compounds are limited to a few subdivisions.

And now, if we find prussic acid in a plant, is it always of the same significance? Is it always a material for proteid formation, as it probably is in *Pangium edule* and *Phaseolus lunatus*? I do not think so. The presence of the same substance in different orders or genera may be a proof of natural relationship showing itself in the plant by similarities in its chemistry, but this need not always be the case; the same substances may arise in plants in very different ways.

Let us pass on to another prussic-acid plant, which has been studied thoroughly, i.e. the cherry laurel. Here, and in all rosaceous plants, the linking of the hydrocyanic acid to other substances is much stronger than in the plants examined by Treub, and is of a different type. Further, the acid is not so definitely localised. In the dark the cyanogenetic compound disappears less easily, and it even seems to be formed in the dark. The rôle of hydrocyanic acid as the first visible assimilation product of the nitrogen is not very evident in this case. The fact that in the sweet almond no trace of amygdalin is present, and that only after germination that body is found there, can be explained in other ways than in the assumption that it takes part in proteid synthesis. Again, such a complicated substance as lotusin more closely resembles a decomposition product than an early product of phyto-synthesis.

Certainly we must be careful in generalising about the rôle of prussic acid in plants.

The most important point to determine in the first instance is whether the acid occurs free or loosely combined and circulating in the plant, or combined into a definite substance to be used as a reserve material. The nature of hydrocyanic acid is such as to allow of its production in different physiological processes by the disruption of the albumen molecule.

In my list of prussic-acid plants I have mentioned, so far as is known, the manner in which the hydrocyanic acid occurs. The two most important forms are (1) combination with acetone, marked *A*; and (2) with benzaldehyde, marked *B*. *n.B.* means that we know with certainty that benzaldehyde is not split off.

I propound the question: Does a physiological difference exist between those two large chemical groups, the acetonecyanohydrin and the benzaldehydecyanohydrin? On chemical grounds the acetonecyanohydrin may be regarded as a primary material for proteid synthesis. Treub's plants belong to the first group, in which prussic acid is loosely combined with acetone, and where the greater part of the prussic acid is free and cannot be isolated in the combined form.

With benzaldehydecyanohydrin plants, such as *Prunus* and other *Rosaceæ*, the prussic acid is associated with benzaldehyde as a stable glucoside, and it is not so clear that benzaldehyde could serve as a primary material for proteid formation. Nevertheless, is it not wholly impossible, since the proteid molecule contains aromatic groups, and the step from benzaldehydecyanohydrin to tyrosin is not an unthinkable one in phyto-synthesis?

Many plant physiologists in Europe, with more experience with *Prunus* or amygdalin than with the tropical *Pangium*, incline to the view that hydrocyanic acid in these plants has nothing to do with either the building-up or the breaking-down of proteids, but that this substance is made by the plant from sugar and nitrate by a special process, and serves no other purpose than to defend the plants against the attacks of animals. It is, above all, the incompleteness of our physiological knowledge which makes decision between these theories difficult.

In the study of this question it is important to remember the possible diversity of origin of this body, and every cyanogenetic plant will be required to be examined on the lines laid down by Treub. I hope my paper has shown how necessary is the co-operation of botany and chemistry in this work, and how much every botanical garden which aspires to be something more than a mere collection of plants needs a chemical laboratory.

Allow me to conclude with the words of Professor Czapek, in his recent 'Biochemistry of Plants' (ii. 1905, p. 259), who closes his chapter on this subject as follows:—

'Die ganze Blausäurefrage bedarf eines gründlichen, umfassenden Studiums, da es sich unstreitig um physiologisch wichtige Stoffwechselforgänge handelt, und die Bildung cyanhydrin- oder nitrilartiger Substanzen möglicherweise im Chemismus der Zelle eine bedeutungsvolle Rolle spielt.'

The Chemical Aspects of Cyanogenesis in Plants. By Professor WYNDHAM DUNSTAN, M.A., LL.D., F.R.S., and T. A. HENRY, D.Sc.

[Ordered by the General Committee to be printed *in extenso*.]

THE production of prussic acid by a plant was recorded for the first time by a Berlin pharmacist named Böhm,¹ who obtained it by distilling water, which had been in contact with crushed bitter almonds. Since then the formation of this highly poisonous substance, under conditions similar to those noted by Böhm, has been observed by many investigators working on widely different plants, and at the present time considerably more than a hundred plants, belonging to twenty-two different natural orders, have been observed to yield prussic acid. During recent years considerable progress has been made in the investigation of this phenomenon (which may conveniently be referred to as 'cyanogenesis'), especially in elucidating the nature of the immediate precursors of the acid in plants and the processes by which it is liberated.

NATURE OF 'CYANOGENESIS.'

In the great majority of cases in which the isolation of prussic acid from a plant has been recorded no attempt has been made to ascertain whether it occurs free or is produced by the decomposition of some more complex primary substances occurring in the plant. Indeed, it has been assumed that the acid occurs free in many of the plants in which it has been found.

In all plants in which 'cyanogenesis' has been thoroughly investigated it has been shown that although some free prussic acid may exist, there is always present in addition a cyanogenetic glucoside, which is readily decomposed by an associated enzyme, yielding the acid.

Until quite recently only one of these cyanogenetic glucosides—viz., amygdalin—was well known, but during the last few years, since our discovery of lotusin in 1901, and of dhurrin in 1902, several additions have been made to this class of substances.

Amygdalin.

This, the best-known member of the class, was isolated from bitter almonds by Robiquet and Boutron-Charlard in 1830,² and was first thoroughly investigated by Liebig and Wöhler.³ It has the formula $C_{20}H_{27}O_{11}N$, and on hydrolysis by the enzyme emulsin, which occurs both in sweet and bitter almonds, or by hot dilute mineral acids, yields a molecule each of prussic acid and benzaldehyde and two molecules of dextrose.

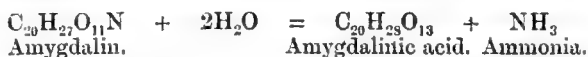


¹ *Neues Allgemeines Journal der Chemie*, 1803.

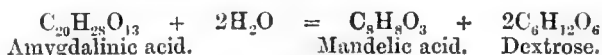
² *Ann. Chim. Phys.*, 1830 (ii.), 44, 352.

³ *Ann. Chem. Pharm.*, 1837, 22, 11.

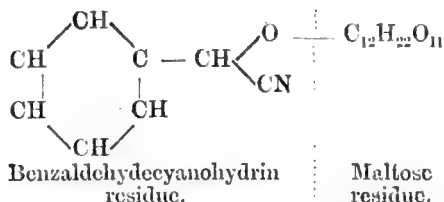
Amygdalin is also decomposed hydrolytically when boiled with alkalis or strong mineral acids, yielding amygdalinic acid and ammonia.



Amygdalinic acid, on further treatment with hot, dilute, mineral acids, yields one molecule of mandelic acid and two molecules of dextrose.



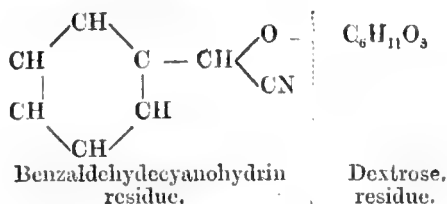
From these data it is clear that amygdalin is probably the maltose ether of benzaldehydecyanohydrin, and that its constitution must be represented by the following formula:—



Mandelic Nitrile Glucoside.—This substance is the glucosidic hydrolytic product obtained by Fischer,¹ by the action of the enzyme maltase of yeast on amygdalin, and has the formula $\text{C}_{14}\text{H}_{17}\text{O}_6\text{N}$. Having regard to its method of formation and to the fact that on further treatment with the enzyme emulsin or with hot, dilute, mineral acids it is hydrolysed, yielding one molecule each of prussic acid, benzaldehyde, and dextrose—



—it must be a β dextrose ether of benzaldehydecyanohydrin, and be represented by the following formula:—



Sambunigrin.

This glucoside was isolated from the leaves of the common elder (*Sambucus nigra*) by Bourquelot and Danjou,² although Guignard had almost simultaneously recorded the presence in the leaves of a substance which underwent hydrolysis, yielding prussic acid and benzaldehyde.³ It is isomeric with Fischer's mandelic nitrile glucoside, but differs from it in melting-point and in exhibiting a much higher levorotation.

Prulaurasin.

This substance was obtained for the first time in a pure state from the leaves of the common laurel (*Prunus Laurocerasus*) by Herissey,⁴

¹ *Ber.*, 1894, 27, 2989; 1895, 28, 1809.

² *Compt. Rend.*, 1905, 141, 598.

³ *Ibid.*, 1905, 141, 236.

⁴ *Ibid.*, 1905, 141, 959.

though Simon,¹ Michelsöhn,² Lehmann,³ and Jouck⁴ had previously obtained the glucoside in an impure state. In this impure form it was known as 'laurocerasin,' or 'amorphous amygdalin.' The production of prussic acid when laurel leaves are crushed and moistened with water was first recorded by Schröder,⁵ and subsequently by Winkler, who also noticed the presence of benzaldehyde in the distillate.⁶ Prulaurasin is isomeric with mandelic nitrile glucoside and with sambunigrin, and, like both these substances, is hydrolysed by emulsin or by hot, dilute hydrochloric acid, yielding one molecule each of prussic acid, benzaldehyde, and dextrose. The principal properties of these three isomerides are shown in the following table :—

—	Form	Melting-point	Specific Rotation	Hydrolysed by Emulsin into
Mandelic nitrile glucoside	Colourless needles	147°-149°	-26°·1	} 1 mol. each of prussic acid, benzaldehyde, and dextrose
Sambunigrin . .	Colourless needles	151°-152°	-76° 3	
Prulaurasin . .	Colourless long needles	120°-122°	-52°·75	

If it may be assumed that they are different—and the evidence on this point is not as conclusive as is desirable, having regard to the difficulty of isolating these glucosides in a pure state from plants—the differences between them probably lie in the nature of the sugar residue, and it is desirable that the sugars produced from them on hydrolysis should be carefully examined.

Glucosides yielding both prussic acid and benzaldehyde are also known to occur in the barks, seeds, and leaves of a large number of rosaceous plants. Lists of these and references to the literature dealing with them are given by Greshoff in 'Monographia de plantis venenatis et sopientibus quae ad pisces capiendos adhiberi solent,' ii.,⁷ and by Jouck in 'Beiträge zur Kenntnis der Blausäure abspaltenden Glycoside,' Strasburg i. E., 1902. Crystalline glucosides have not been isolated from any of these plants, though in several cases an 'amorphous amygdalin' has been obtained.

Dhurria.

This glucoside was isolated by Dunstan and Henry⁸ from the leaves and stems of the 'great millet' (*Sorghum vulgare*) grown in Egypt. This plant is much cultivated in tropical countries for the sake of its edible grain, which forms one of the staple foods of the natives of India (*juár*), Egypt (*dhurra*), West and East Africa (*matama*), South Africa ('Guinea' or 'Kaffir' corn), the West Indies, the United States, and elsewhere. With the gradual introduction of European methods of agriculture into tropical countries it has become customary to take advantage of the rapidity and ease with which crops of 'great millet' can be obtained to

¹ *Ann. Chem. Pharm.*, 1839.

³ *Neues Repertorium*, 1874, 23, 449.

⁵ *Trommsdorf's Journal*, 1803.

⁷ Published in *Mededeelingen uit 's lands plantentuin*, Batavia, 1900.

⁸ *Phil. Trans.*, 1902, A, 199, 399.

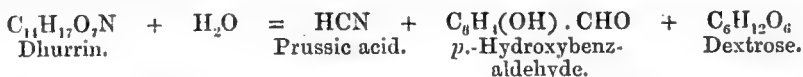
² *Über das Amygdalin*, 1870.

⁴ *Inaug. Diss. Strasburg*, 1902.

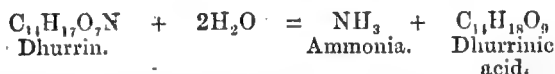
⁶ *Rep. Pharm.*, 1839.

cultivate it for use as forage, and as a result occasional poisoning cases among cattle have occurred in almost all the countries in which this practice has been adopted. The toxicity of sorghum seems to be enhanced in seasons of drought. In Egypt the young plant has long been known to be poisonous, and there it appears never to be applied as a green fodder by the natives.

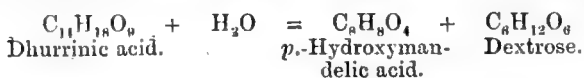
Dhurrin has the formula $C_{14}H_{17}O_{11}N$, and on hydrolysis with hot dilute hydrochloric acid or by emulsin, which occurs in the plant, yields one molecule each of prussic acid, *para*-hydroxybenzaldehyde, and dextrose.



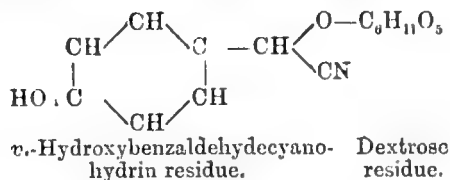
When decomposed by heating with alkalis it yields ammonia and dhurrinic acid.



And the latter, on further hydrolysis by hot dilute acids, decomposes into a molecule each of *p*-hydroxymandelic acid and dextrose.



These reactions are explained by regarding dhurrin as the dextrose ether of *para*hydroxybenzaldehydecyanohydrin, thus:—



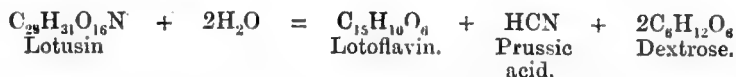
It is probably, therefore, a *para*-hydroxy derivative of mandelic nitrile glucoside or of one of its isomerides.

Lotusin.

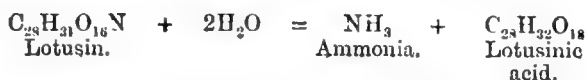
It will be observed that all the cyanogenetic glucosides so far described are of a type in which the cyanogen radicle is attached to the non-sugar portion of the nucleus, forming with it a cyanohydrin. It is, however, obvious that another type may exist, in which the cyanogen radicle is associated with the sugar residue to form a sugar cyanohydrin. The only substance of this second type yet known was obtained¹ from the stems and leaves of an Egyptian plant, *Lotus arabicus*, growing along the valley of the Nile, where it is known as 'khuther.' The Arabs have long known that it is poisonous in the early stages of its growth, and that it becomes a useful forage when allowed to mature. The plant was a great source of trouble to the Anglo-Egyptian army during the first Sudanese war, since many of the transport animals were poisoned by eating it. This led eventually to its investigation at the Imperial Institute, and it

¹ Dunstan and Henry, *Phil. Trans.*, 1901, B, 194, 515.

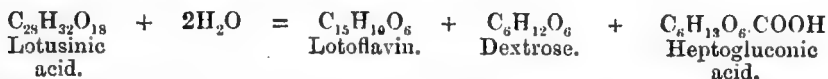
was observed to produce prussic acid when ground and moistened with water, and the acid was found to be derived from a glucoside, which was named lotusin. This is pale yellow in colour, and has the formula $C_{28}H_{31}O_{16}N$. When hydrolysed by a specific enzyme *lotase*, which occurs in the same plant, or by boiling it with dilute hydrochloric acid, lotusin furnishes two molecules of dextrose and one molecule each of prussic acid and a yellow dye, lotoflavin.



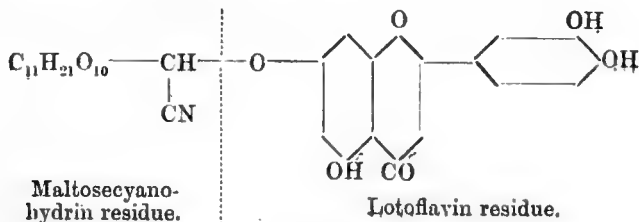
When decomposed by boiling with dilute alkalis the glucoside furnishes ammonia and lotusinic acid.



And the latter, when boiled with dilute hydrochloric acid, decomposes into lotoflavin, dextrose, and heptogluconic acid.



The dye lotoflavin is liberated as a final product both in the acid and alkaline hydroyses of lotusin, and one of the dextrose residues is obtained as heptogluconic acid in the alkaline hydrolysis. These reactions indicate that the cyanogen radicle in lotusin must be associated with the sugar residue, and that it is probably a lotoflavin ether of maltosecyanohydrin. Lotoflavin also possesses a much more complicated structure than that of similar decomposition products of cyanogenetic glucosides. It is isomeric with the dyes luteolin and fisetin, obtained respectively from the yellow dyestuff 'weld' and 'young fustic'; and, like its isomerides, has been shown to be a flavone derivative, and to differ from each of them in the positions occupied by one of the four hydroxyl groups. The constitution of lotusin may be represented as follows:—



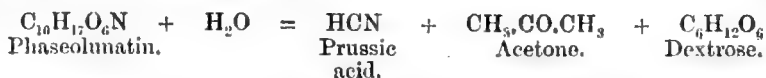
The precise position of attachment of the lotoflavin residue to the sugar-cyanohydrin residue has not been determined.

Phaseolunatin.

The cyanogenetic glucosides mentioned above include all those definitely known to contain a cyclic nucleus. Phaseolunatin differs from these in having an aliphatic nucleus.

It was first obtained from the beans of *Phaseolus lunatus*, L., grown in

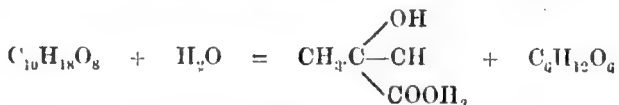
Mauritius.¹ It has the formula $C_{10}H_{17}O_6N$, and on hydrolysis by an enzyme present in the beans, or with dilute acids, yields a molecule each of prussic acid, acetone, and dextrose.



Alkalis hydrolyse it into phaseolunatinic acid and ammonia—

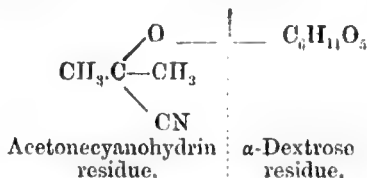


—the former breaking up on further hydrolysis by acids into one molecule, each of hydroxyisobutyric acid and dextrose.



Phaseolunatinic acid. Hydroxyisobutyric acid. Dextrose.

The glucosidolytic enzymes present in the beans of *Phaseolus lunatus* are of special interest. The mixture of enzymes, prepared from the beans in the usual way, contains at least two glucosidolytic enzymes—one of the emulsin type and the other of the maltase type; and it is the latter which attacks phaseolunatin. Examination of the dextrose produced by the hydrolysis of phaseolunatin by the maltase-like enzyme present in the beans shows that it is the α -isomeride, so that phaseolunatin is an α -glucoside, and may therefore be represented as the α -dextrose ether of acetonecyanohydrin.



A paper dealing with the constitution of the sugar residue of phaseolunatin will shortly be communicated to the Royal Society.

Phaseolunatin has been identified² with the linamarin first isolated by Jorissen and Hairs from young flax plants,³ and it has also been proved to be the source of the prussic acid yielded by bitter cassava.⁴ It is probable, also, that phaseolunatin, or a similar glucoside, is the source of the acetone and prussic acid obtained from *Manihot Glaziovii* (the Ceara rubber plant) and from *Hevea brasiliensis* (the Para rubber plant) by Van Romburgh,⁵ and also from *Thalictrum aquilegifolium*, by Van Itallie.⁶

Gynocardin.

This glucoside was isolated by Power and Gornall⁷ from the oleaginous seeds of *Gynocardia odorata*, and was subsequently investigated by Power and Lees.⁸ It has been assigned the formula $C_{13}H_{19}O_9N$, and is hydro

¹ Dunstan and Henry, *Proc. Roy. Soc.*, 1903, **72**, 285.

² Dunstan, Henry, and Auld, *Proc. Roy. Soc.*, 1906, **B**, **78**, 145.

³ *Bull. Acad. Roy. Belg.*, 1891, iii, **21**, 529.

⁴ Dunstan, Henry, and Auld, *Proc. Roy. Soc.*, 1906, **B**, **78**, 152.

⁵ *Ann. Jard. Bot. Brit.*, 1899, ii, **16**, 1.

⁶ *Journ. Pharm. Chim.*, 1905, vi., **22**, 337.

⁷ *Proc. Chem. Soc.*, 1904, **20**, 137.

⁸ *Journ. Chem. Soc.*, 1905, **87**, 349.

lysed by the enzyme gynocardase, present in the seeds, and by hot dilute mineral acids, yielding one molecule each of prussic acid, dextrose and a substance having the composition $C_6H_8O_4$. The latter has not been isolated, as it passes immediately into a brown, amorphous resin. On alkaline hydrolysis gynocardin yields gynocardinic acid, which may, in turn, be hydrolysed by dilute acids into dextrose and an acid of the formula $C_7H_{10}O_6$. The exact nature of gynocardin and its decomposition products remains to be determined.

In addition to the glucosides mentioned, which have been isolated from the several plants referred to, there can be little doubt that similar substances exist in all the plants in which cyanogenesis occurs, and in a few cases indications of the existence of such compounds have been observed.

In *Pangium edule* Treub suggests¹ that the prussic acid may be loosely combined with a sugar also found in the plant. Power and Gornall² have shown that a peculiarly unstable cyanogenetic substance exists in the seeds of *Taraktogenos Kurzii*, and Easterfield and Aston observed that the 'karakā' fruit (*Corynocarpus levigata*) of New Zealand yields prussic acid, probably produced by the action of an enzyme on the glucoside karakin, contained in the fruit.³

ENZYMES ASSOCIATED WITH CYANOGENETIC GLUCOSIDES.

All these cyanogenetic glucosides are accompanied in the plants by enzymes which decompose them, yielding products identical with those obtained by the action of hot dilute acids.

There is as yet no method available of characterising enzymes, except in a very general manner by the nature of their activities. The enzymes present in these various plants cannot, therefore, be identified with certainty, but it may be convenient to summarise what has been done in the way of associating enzymes with the cyanogenetic glucosides they have been found capable of decomposing.

Emulsin of Sweet or Bitter Almonds.

This decomposes amygdalin, mandelic nitrile glucoside, prulaurasin, sambunigrin, and dhurrin, but does not hydrolyse lotusin or phaseolunatin. It has been pointed out by Fischer⁴ that emulsin hydrolyses only those glucosides which contain β -dextrose residues. Hence the five first-mentioned substances must be β -glucosides.

Lotase.

This hydrolyses lotusin, the characteristic glucoside of *Lotus arabicus*, and also decomposes amygdalin and salicin. On the contrary, the emulsin of almonds has practically no action on lotusin. It may therefore be assumed that lotase is not identical with the emulsin of almonds.

Gynocardase.

This decomposes gynocardin and amygdalin, and may be identical with emulsin.

¹ *Ann. Jard. Bot. Buit.*, 1896, vol. xiii.

² *Trans. Chem. Soc.*, 1904, 85, 841.

³ *Proc. Chem. Soc.*, 1903, 19, 191.

⁴ *Zeit. Physiol. Chem.*, 1899, 26, 60.

Maltase.

This partially hydrolyses amygdalin, forming mandelic nitrile glucoside, and decomposes phaseolunatin, yielding acetone, prussic acid, and α -dextrose.

Since the mixture of enzymes prepared from the beans of *Phaseolus lunatus* completely hydrolyses both amygdalin and phaseolunatin, it must be assumed that these beans contain at least two enzymes, the one identical with or similar to the emulsin of almonds, and the other identical with or similar to the maltase of yeast. Fischer has shown¹ that maltase only hydrolyses glucosides containing an α -dextrose residue, and in confirmation of this it has been shown² that phaseolunatin yields α -dextrose on hydrolysis by one of the enzymes associated with it in the beans of *Phaseolus lunatus*, which must therefore be of the maltase type.

Mention may also be made of the enzyme isolated by Power and Gornall³ from the seeds of *Taraktogenos Kurzii*, which has the property of hydrolysing amygdalin, but differs from emulsin in also decomposing potassium myronate, the characteristic glucoside of white mustard seed.

It is of interest also to record that an emulsin-like enzyme, capable of decomposing amygdalin and mandelic nitrile glucoside, occurs in yeast,⁴ and that substances exerting similar activities have been noted by Bourquelot in various fungi.

PHYSIOLOGICAL SIGNIFICANCE OF CYANOGENESIS.

In the literature relating to cyanogenesis three main ideas as to the significance of the production of prussic acid in plants may be traced. At first it was regarded as merely a waste product of no metabolic importance; later the view that it was possibly a means of protection was suggested; and more recently a small number of botanists and chemists have put forward the idea that the acid is an intermediate product in the synthesis of proteids.

Evidence in favour of this last view has been accumulated mainly in three ways.

1. *By physiological experiments on plants in which cyanogenesis occurs.*—Two notable contributions have been made to this side of the subject by Dr. Treub, who has studied especially *Pangium edule*⁵ and *Phaseolus lunatus*.⁶ In both these plants prussic acid appears to occur free, and also in the form of a compound (phaseolunatin in the case of *P. lunatus*), from which the acid may be readily released, and which appears to serve as a temporary reserve of the acid, and with more active assimilation in the plants, whether brought about by improvement in nutrition or in environment, there is an increase in the total amount of the acid available in the plant. Whilst Treub has conclusively established that the *living* plant of *Phaseolus lunatus* develops more prussic acid under conditions of improved nutrition, it seems to be equally certain that prussic acid and the cyanogenetic glucoside, phaseolunatin, may be completely eliminated from the seeds or beans of the plant by careful cultivation. Bonamé showed⁷ that of the variously coloured

Dunstan, Henry, and Auld, *Proc. Roy. Soc.*, 1906.

² *Loc. cit.*

³ *Loc. cit.*

⁴ Henry and Auld, *Proc. Roy. Soc.*, 1905, **B**, 76, 568. Compare Husemann, *Pflanzen Stoffe*, p. 1020.

⁵ *Loc. cit.*

⁶ *Ann. Jard. Bot. Buit.*, 1905, ii. 4, 86.

⁷ *Rap. Stat. Agron. Maurice*, 1900, 94.

beans produced by the wild plant in Mauritius those which were darkest in colour yielded most prussic acid. This observation was confirmed by Dunstan and Henry¹ for beans produced from wild plants in Mauritius, and subsequently it was found by these authors that the pale, buff-coloured, semi-cultivated beans produced by *Phaseolus lunatus* in Burma contained only traces of the glucoside, whilst the large white beans produced by careful cultivation of the plant in the South of France contained none. These observations have been confirmed in a general way by Guignard,² Kohn-Abrest,³ and by Tatlock and Thomson,⁴ though the first-mentioned author states that he also obtained traces of prussic acid from the white beans produced by careful cultivation. He has, in addition, shown that the relationship between the depth of colour and the amount of prussic acid yielded by the beans produced by the wild plant in Java is not so clearly marked as is the case with the beans produced in Mauritius.

2. *By the investigation of the distribution of cyanogenetic compounds in the vegetable kingdom.*—To this side of the work many investigators have contributed, but reference may be made more especially to the pioneer work done by Greshoff,⁵ and more recently by van Romburgh,⁶ who have shown that prussic acid is produced by many plants occurring in the Dutch East Indies. Investigations in this direction have also been made by Hébert,⁷ Jouck,⁸ Brünnich,⁹ and others.

3. *By chemical investigation of the progress of cyanogenesis in plants.*—Work of this kind has been done by Jorissen and Hairs¹⁰ as regards flax, by Jorissen¹¹ and Marco Soave¹² as regards the sweet almond, by Brünnich¹³ for a number of grasses cultivated in Queensland, by Hébert,¹⁴ and by Dunstan and Henry¹⁵ for the various plants they have investigated.

The results of this work, taken generally, go to show that in cases where there is little or no cyanogenetic glucoside in the seed (e.g. *Lotus arabicus*, the sweet almond, linseed, and sorghum) there is on germination a large and rapid increase in the total amount of prussic acid available. Thus whereas flax seed yields only 0.008 per cent. of prussic acid, flax embryos four to five inches high yield as much as 0.135 per cent.; and, similarly, whilst sweet almonds yield the merest traces of the acid, almond embryos eight days old furnish as much as 0.04 per cent. Further, it has been proved in the case of flax, sorghum, *Lotus arabicus*, and maize that the percentage of prussic acid available reaches a certain maximum, and then diminishes, in some cases to zero. The stage at which this maximum occurs varies with different plants. Thus in flax the percentage of acid reaches the maximum when the embryos are about 4.5 inches high. In *Lotus arabicus* the maximum is not attained until the plant reaches the flowering stage; in sorghum it occurs when the plants are about twelve inches high, and in maize when they are about four weeks old. Brünnich has also shown¹⁶ that with maize and sorghum

¹ *Proc. Roy. Soc.*, 1903, 72, 285.

² *Compt. Rend.*, 1906, 142, 586.

³ Compare Dunstan and Henry, *Compt. Rend.*, 1906.

⁴ *Loc. cit.*

⁵ *Loc. cit.*

⁶ *Loc. cit.*

⁷ *Nuovo Giorn. Bot. Ital.*, 1899, 6, 219.

⁸ *Ann. Agron.*, 1898, 416.

⁹ *Ann. Agron.*, 1898, 416.

¹⁰ *Compt. Rend.*, 1906, 142, 545.

¹¹ *Analyst*, August 1906.

¹² *Compt. Rend.*, 1906.

¹³ *Bull. Soc. Chim.*, 1896, iii, 15, 216.

¹⁴ *Journ. Chem. Soc.*, 1903, 83, 783.

¹⁵ *Ann. Agron.*, 1885, 10, 468.

¹⁶ *Loc. cit.*

¹⁷ *Loc. cit.*

manuring has the effect of increasing the yield of prussic acid, and, similarly, Treub¹ found that the application of potassium nitrate led to an increased production of prussic acid in plants of *Phaseolus lunatus*.

The results obtained by the prosecution of investigation in these three directions lend support to Treub's view that prussic acid plays some important part in plant metabolism, and is probably a step in the process by which these plants convert the 'inorganic' nitrogen of nitrates into the 'organic' nitrogen of proteids.

It may be worth while, therefore, to refer to the various theories of proteid formation in plants, which have been put forward in which prussic acid is regarded as a basis of proteid synthesis, or in which its widespread occurrence in plants is accounted for.

On the theoretical side Pflüger² regarded the cyanogen radicle as a most important factor in the constitution of the proteid molecule, and advanced the hypothesis that whereas in ordinary proteid the nitrogen probably occurs in the form of amino groups, in the molecule of living protoplasm it was probably present in the form of cyanogen radicles. Dr. P. W. Latham, in his Croonian Lecture on 'Some Points in the Pathology of Rheumatism, Gout, and Diabetes,' also assigns an important rôle to the cyanogen radicle and to prussic acid in the constitution and natural synthesis of animal proteids.³

From the chemical side, however, more importance attaches to the views put forward by Victor Meyer and Schulze, Bach and Gautier. Meyer and Schulze suggested⁴ that the nitrates in cell-sap are first reduced to hydroxylamine, which combines with the various aldehydic and ketonic substances occurring in plants forming aldoximes and ketoximes, and that the oximino group subsequently undergoes reduction to an amino group. Bach's explanation⁵ greatly extended that put forward by Meyer and Schulze. This investigator supposed that, from the small amount of nitrate present in cell-sap, nitric acid was liberated in minute amount by the considerable quantities of oxalic and carbonic acids usually present, and that this free nitric acid was continuously reduced by formaldehyde, producing hydroxylamine, which immediately combined with formaldehyde, forming formaldoxime. The latter might then undergo transformation in two ways. It might be converted into the isomeric formamide, which by simple dehydration would give prussic acid and water, and in this way account for the frequent occurrence of this acid in plants, or the formamide might be hydrolysed, yielding ammonium formate, so supplying ammonia and formic acid.

There may be a fundamental objection to this view. Meyer and Schulze have themselves shown that hydroxylamine is poisonous towards protoplasm, but this difficulty of the generation in the plant of a substance which is toxic to protoplasm, also occurs in the formaldehyde hypothesis of the phytosynthesis of carbohydrates, and may perhaps be overcome by assuming that the hydroxylamine as it is formed is immediately converted into a stable and innocuous oxime.

On the other hand, there is indirect physiological evidence in favour of this view. Thus the supposition that the reduction of nitric acid is accomplished by formaldehyde is in harmony with the observation that, whilst nitrates occur abundantly in stem structures of green plants, they are

¹ *Loc. cit.*

³ *Brit. Med. Journal*, 1886, 1, 629.

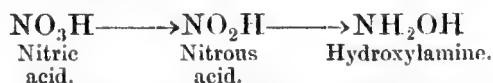
⁵ *Moniteur Scientifique*, 1897, iv, 11, 1.

² *Archiv für Physiologie*, 1875, 10, 251.

⁴ *Ber.*, 1884, 41, 1554.

either entirely absent or are present in diminished amount in the leaves—*i.e.*, in the organs in which it is generally assumed the formation of formaldehyde is most actively proceeding. Moreover, several investigators have stated on other grounds that the reduction of nitrates is most active in the leaves.

While there is no experimental evidence of the production of hydroxylamine when nitric acid reacts with formaldehyde, there can be no objection on theoretical grounds to Bach's hypothesis¹ that nitric acid in contact with formaldehyde undergoes reduction in the following steps:—



especially since he has obtained indirect evidence of the formation of hydroxylamine by the action of nitric acid on trioxymethylene.

The isomeric change of formaldoxime into formamide, the decomposition products of which Bach has detected in the products of the action of trioxymethylene on nitric acid, is probable, since Dunstan and Bossi have shown that formaldoxime yields ammonia and formic acid when boiled with dilute hydrochloric acid,² and the dehydration of formamide to form prussic acid and water has been recorded by Scholl,³ whilst its hydrolysis into formic acid and ammonia is a familiar chemical reaction.

A further fact in favour of Bach's view may be mentioned. It is well known that *Sorghum vulgare* is most poisonous when grown in very dry climates. This is precisely the condition in which natural dehydration would occur, and if Bach's view be adopted it might be expected that in seasons of drought an unusually large proportion of the formamide in sorghum would be dehydrated and an abnormal production of prussic acid take place. Similar observations have been made with regard to cassava, which is peculiarly virulent when grown in the dry districts of South America, but, according to Wiley, yields much less prussic acid when grown under moist climatic conditions, as in the West Indies or the United States. It is also worth mentioning in this connection that Leather has obtained a much larger proportion of prussic acid from flax (linseed) plants grown in India than has been recorded by European workers who have investigated flax plants grown in colder and moister climates.

It will be observed that Bach offers no suggestion that prussic acid takes any further part in the metabolic process, and he apparently regards it as an accidental product of little importance.

Gautier's theory⁴ differs fundamentally from those of Meyer and Schulze and Bach. This author supposes that the free nitric acid of cell sap reacts with formaldehyde, forming free prussic acid, carbon dioxide, and water. It is then suggested that the prussic acid formed, condenses with formaldehyde, forming a chain such as



in which it is supposed that the $\equiv \text{C} \cdot \text{NH}$ groups undergo hydrolysis and

¹ *Moniteur Scientifique*, 1897, iv. 11, 1.

² *Journ. Chem. Soc.*, 1898, 73, 354.

³ *Ber.*, 1891, 573.

⁴ *Bull. Soc. Chim.* 1872, 42, 141, and *Leçons de Chimie Biol.*, Paris, Masson et Cie., 1897.

the $\cdot\text{CHOH}\cdot$ and $\cdot\text{NH}\cdot\text{CHOH}\cdot$ groups reduction, giving rise eventually to chains of the type



which are regarded as forming the unit of the proteid molecule.

Gautier's *explanation* of the formation of proteids from formaldehyde and prussic acid as primary materials is purely speculative, and has at present no experimental evidence to support it. Yet there is much to be said for his view that prussic acid is an important factor in plant metabolism, and support for it is found in the fact that the acid is widely distributed in plants, and that Treub's botanical researches on *Pangium edule* and *Phaseolus lunatus* indicate that prussic acid is concerned in the metabolism of these plants. The fact that prussic acid is not obtainable from all plants does not invalidate this theory, since the acid may be a plastic substance which is immediately utilised in the metabolism of the plant.

Hébert has brought forward a series of observations made on the columbine (*Aquilegia vulgaris*) which lend some support to Gautier's view as to the method of production of prussic acid. In this plant prussic acid is obtainable from the stems, leaves, and unopened flower-buds, but not from the roots. In the fully developed flowers none is produced by the calyx or stamens, neither of which contain chlorophyll, but considerable quantities can be obtained from the ovary, which is chlorophyllaceous. From these results Hébert draws the conclusion that in *Aquilegia vulgaris* the formation of prussic acid is dependent on the formation of formaldehyde.

Treub, on the contrary, has shown that in *Phaseolus lunatus* and *Pangium edule* the production of the acid is not directly dependent on the energy derived from light, but is influenced mainly by the supply of sugar available. This observation has led Treub to modify Gautier's theory, and to suggest that the reduction of nitric acid in the cell-sap is brought about by the action of a sugar on the acid.

Professor Meldola in his recent presidential address to the Chemical Society, 'The Living Organism as a Chemical Agency,'¹ says, in reference to the theories of Bach and Gautier (wrongly attributed to Hébert in the address) that on careful consideration these do not appear very plausible, and that for these views 'there is at present practically no evidence either from the physiological or chemical side.' This statement is perhaps rather stronger than is warranted by the facts of the case, and a fairer position is that taken up by Treub, who concludes his memoir on *Phaseolus lunatus* by saying: 'Il serait prémature de vouloir expliquer, en partant de l'acid cyanhydrique, l'origine des différents corps reconnus dans la plante comme précurseurs des substances albuminoïdes. Le moment d'entrer dans des discussions de cette nature ne sera venu que lorsque les vues hypothétiques émises ici auront été confirmées par les résultats de nouvelles recherches, entreprises sur d'autres plantes.' Czapek, in his recently issued 'Biochemie der Pflanzen' (vol. ii., p. 259), says: 'Die ganze Blausäurefrage bedarf eines gründlichen umfassenden Studiums, da es sich unstreitig um physiologisch wichtige Stoffwechselfvorgänge handelt, und die Bildung cyanhydrin- oder nitrilartiger Substanzen möglicherweise im Chemismus der Zelle eine bedeutungsvolle Rolle spielt.'

¹ *Journ. Chem. Soc.*, 1906, 89, 765.

Much experimental work, however, still remains to be done in order to substantiate the view that the prussic acid originates in the plants from nitrates, and especially to trace the exact mechanism of this process, and also to ascertain the reaction into which the prussic acid subsequently enters and the nature of the compounds formed.

Dynamic Isomerism.—*Report of the Committee, consisting of Professor H. E. ARMSTRONG (Chairman), Dr. T. M. LOWRY (Secretary), Professor SYDNEY YOUNG, Dr. J. J. DOBBIE, Dr. A. LAPWORTH, and Dr. M. O. FORSTER. (Drawn up by the Secretary.)*

ATTENTION has been directed during the past two years mainly to the determination of the proportions in which isodynamic compounds are in equilibrium in solution. The method of investigation, which was briefly referred to in the last report,¹ involves the measurement of the solubility of one of the isomerides, both before and after isomeric change has taken place. Only one of the solid isomerides can persist in stable equilibrium with the solution. This is not necessarily the form which predominates in the liquid; indeed, the modification which thus persists may vary with the solvent² and differ in closely related compounds (compare nitro-camphor and its π -bromo derivative). The concentration of the original compound is kept substantially constant by stirring the solution with an excess of the solid; any increase which is observed in the concentration of the saturated solution is attributed to the formation in the liquid of one or more dynamic isomerides. If the initial concentration of the saturated solution be A and the final concentration B, the ratio A/B affords a measure of the proportion of the original material present in the solution when equilibrium between the dynamic isomerides is attained.

In applying the method experimentally certain difficulties are encountered.

(1) When isomeric change occurs rapidly, the products appear in the solution before the latter is saturated with the original material. In such cases it is necessary to make solubility-measurements at frequent intervals during the early stages of the experiment and to deduce the initial value by extrapolation. When, however, isomeric change proceeds slowly or only after the addition of a catalyst, the measurements can be made at leisure and the experimental errors are very greatly reduced.

(2) Whether isomeric change be rapid or slow, it is essential that the solid used in effecting saturation consist wholly of one isomeride. To ascertain if this be the case, the sample should be extracted at constant temperature with successive quantities of the solvent; if the material be pure, the different extracts should have equal concentrations. In comparing different series of observations those which give the smallest ratio of initial to final concentration are the more likely to be correct.

(3) In deducing the proportion of the original material present in the solution, it has been assumed that the solubility of this form remains constant throughout the experiment and is not affected by the products of isomeric change. This cannot, as a rule, be tested directly, since the method is of greatest value in cases in which the less stable isomerides are unknown or cannot be prepared in a pure state. Important evidence

¹ Cambridge, 1904, p. 218; compare Lowry, *Proc.*, 1903, 19, 156.

² Dr. Whiteley, *Trans.*, 1899, 75, 231.

can be obtained, however, by studying the effect of adding to the solvent known quantities of a pure substance of allied structure. Experiments have been made on the influence of glucose on the solubility of galactose, by Mr. Robertson on the influence of β -methylglucoside on the solubility of the α -glucoside, on the influence of $\alpha\pi$ -dibromocamphor on the solubility of the $\alpha\pi$ -isomeride and of bromocamphor π -sulphonamide on that of the β -sulphonamide: these have shown that in the case of sparingly soluble compounds of high melting-point the change of solubility is insignificant. In the case of soluble compounds of low melting-point the effects produced are no longer negligible, but the correction to be applied may be estimated by similar methods. In the most extreme case that has yet been examined the correction amounts to 2 per cent. on the volume concentration or 4 per cent. on the weight concentration.

Since the appearance of the last report four investigations dealing with the subject have been completed and described; briefly summarised, the results obtained are as follows:—

1. *Nitro-derivatives of Camphor*.¹—The solubility of normal nitrocamphor in light petroleum increases in the course of a few hours in the ratio 0.82 : 1, indicating that when equilibrium is attained the normal and pseudo forms are present in the ratio 82 : 18 or 5 : 1 approximately. In the case of the π -bromo derivative, the pseudo-form is that which persists in contact with the solution: its solubility increases in the ratio 0.17 : 1; the isomerides are therefore present in the ratio 83 : 17 or (as in the case of nitrocamphor itself) 5 : 1 approximately.

2. *Glucose and Galactose*.²—In methyl-alcoholic solutions one half of the sugar is in the α -form, the other half probably consisting almost entirely of the stereoisomeric β -sugar. In presence of water the proportion of the α -sugar decreases: this might be due to a displacement of the equilibrium between the α and β sugars but is more probably due to the formation of a largely increased proportion of a third form of the sugar, such as the aldehyde or its hydrate. The formation of some such intermediate compound in which the terminal carbon atom is no longer asymmetric appears to be essential to account for the optical inversion which accompanies the interconversion of the α and β sugars.

3. *Bromocamphor and Chlorocamphor*.³—Kipping has shown⁴ that these compounds, although stable in neutral solutions, undergo reversible isomeric change in presence of alkalis. This change is accompanied by an increase of solubility in the ratio 0.89 : 1; a similar increase is observed in the case of the β and π bromo-derivatives of these compounds. In the case of chlorocamphor and bromocamphor the proportions of the α -compounds in the solutions are probably somewhat greater than 89 per cent. owing to the influence of the α' -compound in increasing the solubility of the α -compounds. The proportions are estimated at 91 per cent. and 93 per cent. respectively.

4. *Sulphonic Derivatives of Camphor*.⁵—Kipping has shown⁶ that the π -sulphonic salts derived from α -bromocamphor and α -chlorocamphor undergo reversible isomeric change in presence of a trace of free alkali. Solubility measurements indicate that similar changes take place in the case of the β -sulphonic salts, amides and other derivatives but the observations are complicated by the fact that the compounds of the

¹ Lowry and Robertson, *Trans.*, 1904, **85**, 1541–1550.

² Lowry, *Trans.*, 1904, **85**, 1551–1570.

³ Lowry, *Trans.*, 1906, **89**.

⁴ *Proc.*, 1905, **21**, 125.

⁵ Lowry and Magson, *Trans.*, 1906, **89**.

⁶ *Proc.*, 1905, **21**, 124.

$\alpha\beta$ -series are able to pass not only into stereoisomeric $\alpha'\beta$ compounds but also into isomeric sulpholactones. A number of the latter have been examined and described.

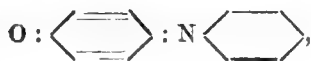
The expenses incurred in connection with investigations described above were in part defrayed by a grant made to the Committee in 1904. It is proposed during the coming year to undertake a detailed examination of the optical properties of nitrocamphor and other compounds which exhibit dynamic isomerism in solution. In particular it is proposed to test Biot's hypothesis that anomalous rotatory dispersion is due to the presence in solution of two modifications of a substance—a suggestion which was made some years before the phenomena of dynamic isomerism were clearly understood.

The Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives.—Report of the Committee, consisting of Professor F. S. KIPPING (Chairman), Professor K. J. P. ORTON (Secretary), Dr. S. RUHEMANN, Dr. A. LAPWORTH, and Dr. J. T. HEWITT.

I. Nitroamines.

IN continuation of previous work on the transformations of aromatic nitroamines¹ a study of the reactions of *s*-tribromonitroaminobenzene has been undertaken.

Under conditions which lead to the isomeric change of unsubstituted nitroaminobenzenes, that is, treatment with sulphuric acid in acetic acid solution, the *s*-tribromonitroamine is largely converted into 2 : 6-dibromo-4-nitroaniline, a bromine atom being displaced from the para position by the nitro group. If the reaction, however, is carried out under narrowly defined conditions, namely, in a mixture of acetic acid 2 parts and sulphuric acid 1 part, which contains 4–5 per cent. of water (this proportion of water is essential), other changes are observed, bromophenyliminoquinones, derivatives of the compound,

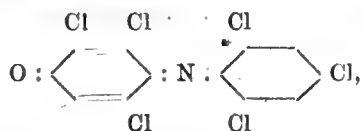


being formed. *s*-Tribromonitroaminobenzene behaves in this respect as does *s*-trichloronitroaminobenzene, which yields hexachlorophenyliminoquinone; but in the case of *s*-trichloronitroaminobenzene a chlorine atom is not displaced by the nitro-group from the para position, and consequently no dichloronitroaniline is formed.

In contrast to the *s*-trichloro-analogue, which yields only one phenyliminoquinone, the tribromonitroaminobenzene gives a mixture of a penta- and hexa-bromophenyliminoquinone; the former melts at 170°, and on reduction is converted into a pentabromohydroxydiphenylamine, melting at 156°; and the latter melts at 135°, and yields a hexabromohydroxydiphenylamine, melting at 207°.

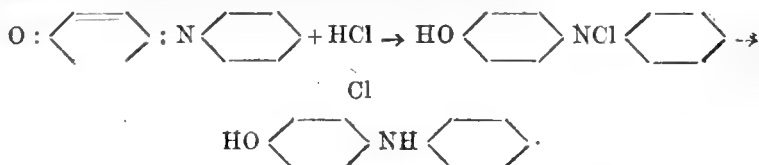
¹ See *Report*, 1905, and compare Orton, *Trans. Chem. Soc.*, **81**, 806; and Orton and Smith, *ibid.*, **87**, 389.

In the formation of the hexachlorophenyliminoquinone,



from *s*-trichloronitroaminobenzene, a chlorine atom must, it is clear, be transferred from one carbon atom of the benzene ring to the neighbouring carbon atom. In the case of the *s*-tribromonitroaminobenzene, on the other hand, it would appear that the detached bromine atom only partly recombines with the neighbouring carbon; hence a mixture of phenyliminoquinones is formed.

Reaction of Phenyliminoquinones with Hydrogen Chloride.—The phenyliminoquinones interact with hydrogen chloride in a very interesting way, forming a chlorohydroxydiphenylamine, thus :



An additive product, a chloroamino derivative, is possibly first formed, which then passes into a diphenylamine, the chlorine wandering into one of the nuclei, and taking up an ortho or para position with respect to the nitrogen atom.

This interpretation of the change is strengthened by the fact that hexachlorophenyliminoquinone does not react with hydrogen chloride in this way; every position into which the chlorine atom could pass from the nitrogen is already occupied by chlorine.

II. *The Exchange of Halogen for Hydroxyl in Benzenediazonium Hydroxides.*

The displacement of halogen by hydroxyl in halogenbenzenediazo-compounds has been studied with substances containing methyl groups, such as the diazotoluenes and diazoxylene. The presence of the methyl group greatly retards the replacement of halogen when the diazonium salts of weak acids are used. In dilute aqueous solution neither bromo-*m*-xylenediazonium acetate nor bicarbonate lose bromine; 3 : 5-dibromo-4-toluenediazonium acetate decomposes very slowly, but the bicarbonate, in the rapidity of its decomposition, approaches the trihalogenbenzenediazonium bicarbonates. Weighting the benzene nucleus with negative groups restores this property; thus 2-nitro-3 : 5-dibromo-4-diazotoluene or 2 : 4 : 6-tribromo-3-diazotoluene lose bromine rapidly in dilute-acetic acid solution.

These facts are in accord with the views previously expressed¹; the bromine is displaced by ionic hydroxyl, (OH)⁻, which is produced in the hydrolytic dissociation of the salts of weak acids. The strong diazonium bases derived from toluene and xylene form acetates which suffer hydrolytic dissociation to a less extent than the halogenbenzenediazonium salts.

Chlorobromobenzenediazo-Compounds.—Mixed halogenbenzenediazo-compounds, containing both chlorine and bromine, have been investigated with the object of comparing chlorine with bromine as regards their dis-

¹ *Trans. Chem. Soc.*, 83, 796.

placement by the hydroxyl group. The four *s*-(chlorobromo)-diazobenzenes and 3-chloro-5-bromodiazotoluene have been chosen for this purpose.

Two facts have been the outcome of these experiments.

When chlorine or bromine occupy similar positions in the benzene ring each is displaced by hydroxyl to an equal extent. No preference appears to be shown to either atom.

Secondly, it has been found that the halogen is not only displaced from the ortho position with respect to the diazo-group, but also from the para position. The latter replacement, however, takes place to a much smaller extent, not more than 10–20 per cent. of the halogen coming from the para position.

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 NORMAN LOCKYER, Professor Sir JAMES DEWAR, Professor G. D. LIVEING, Professor A. SCHUSTER, Professor W. N. HARTLEY, Professor WOLCOTT GIBBS, Sir W. DE W. ABNEY, and Dr. W. E. ADENEY.

CHROMIUM (SPARK SPECTRUM).

Exner and Haschek, 'Sitzber. kaiserl. Akad. Wissensch. Wien,' cvi. (2), 1897.

Adeney, 'Proc. Royal Dublin Soc.,' x. (2), p. 235, 1904.

Lohse, 'Publ. Potsdam Obs.,' No. 41.

Demarçay, 'Spectres électriques,' 1895.

Wave-length (Demarçay)	Intensity and Character	Previous Observations (Hasselberg)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4921.9	3	*4921.9	1.35	5.6	20312.
4886.3	3	4886.11	1.34	"	20460.
70.6	3	70.96	1.33	"	20526.
61.4	2	61.38	"	5.7	65.
29.5	4	29.5	1.32	"	20700.
23.2	1		"	"	27.
01.1	3	01.17	1.31	"	20823.
4792.4	3	4792.61	"	"	61.
67.8	2	67.98	"	5.8	20968.
64.4	2	64.45	1.30	"	83.
56.1	7	56.30	"	"	21020.
52.4	2	52.27	"	"	36.
37.4	4	37.50	"	"	21102.
30.7	4	30.88	"	"	33.
27.0	2	27.33	1.29	"	49.
23.6	2		"	"	64.
18.4	5	18.57	"	"	88.
08.0	4	08.16	"	5.9	21235.
4698.6	5	4698.60	"	"	77.
97.2	2	97.20	"	"	83.
93.9	3	94.12	"	"	98.
88.5	3		1.28	"	21323.

* This was observed by Huggins.

CHROMIUM (SPARK SPECTRUM)—*continued.*

* The measurements of Hasselberg are in the arc.

† Observed also by Demarcay.

‡ Double.

Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney			$\lambda +$	$\frac{1}{\lambda} -$	
4689.54		2	4689.54	1.28	5.9	21318.1
81.02		1	81.01	"	"	57.0
† 80.66		1	80.65	"	"	58.6
† 69.50		1	69.50	"	"	21409.7
67.33		1	67.36	"	"	19.6
† 66.69		2	66.35	"	"	22.6
66.34		ln	66.07	"	"	24.2
66.07		1	64.94	"	"	25.4
64.99		2	63.98	"	"	30.4
† 64.01		2	63.47	"	"	34.9
63.52		2n	56.34	"	"	37.1
56.33		ln	54.90	1.27	"	70.2
54.94		1	52.31	"	"	76.7
† 52.34		7	51.44	"	"	88.7
† 51.48		6	49.58	"	"	92.5
49.61		2n	49.04	"	"	21501.3
49.07		ln	48.27	"	"	03.8
48.30		ln	46.96	"	"	07.3
47.00		ln	46.33	"	"	13.4
† 46.35		8	42.21	"	"	16.3
42.20		ln	39.85	"	"	35.6
39.77		1b	39.69	"	"	46.9
† 37.94		1	37.92	"	"	55.4
37.35		1	37.35	"	"	58.1
† 34.32		6	34.23	"	6.0	72.2
† 33.46		ln	33.45	"	"	76.1
† 32.34		ln	32.32	"	"	81.4
26.35		6	26.31	"	"	21609.3
26.10		1	26.07	"	"	10.5
24.74		1		"	"	16.9
22.95		ln	22.89	"	"	25.3
22.76		1	22.60	"	"	26.1
22.65		1		"	"	26.6
22.11		3	22.07	"	"	29.1
† 19.70		3	19.70	"	"	40.4
19.15		5		"	"	43.0
19.03		5		"	"	43.6
† 16.82		3n		1.26	"	53.9
16.29		7	16.28	"	"	56.5
13.54		6	13.54	"	"	69.3
12.15		6	12.15	"	"	75.9
10.10		ln	10.07	"	"	85.5
06.55		1	06.55	"	"	21702.2
01.20		ln	01.18	"	"	27.5
† 00.92		6	00.92	"	"	28.8
00.28		2	00.25	"	"	31.8
4598.62		1	4598.60	"	"	39.7
† 95.77		3	95.78	"	"	53.1
92.71		ln		"	"	67.6
92.25		4n		"	"	69.8
† 91.59		5	91.56	"	"	72.9

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Previous Observations (Hasselberg *)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney			$\lambda +$	$\frac{1}{\lambda} -$	
4590.2		1b		1.26	6.0	21780.
† 88.42		10	4588.38	"	"	88.0
86.32		1	86.31	"	"	98.0
† 85.2		1b	85.23	"	"	03.
84.26		1	84.26	"	"	07.8
† 80.24		5	80.22	1.25	"	26.9
78.48		1	78.55	"	"	35.3
† 75.30		1	75.26	"	"	50.5
71.86		3	71.85	"	"	66.9
71.3		1	71.27	"	"	70.
† 69.79		2	69.76	"	"	76.8.
65.97		1		"	"	95.1
65.67		3	65.71	"	"	96.6
† 64.36		2	64.36	"	"	21902.9
63.85		1	63.82	"	"	05.3
63.40		1n	63.43	"	"	07.5
† 58.90	4558.92	10	58.81	"	"	29.1
† 56.35	56.43	1	56.32	"	"	41.4
55.20	55.07	5n	{ 55.45 } { 54.98 }	"	"	46.9
54.12	54.11	1n	54.10	"	"	52.1
† 46.13	46.19	7	46.15	"	"	90.7
45.49	45.44	1	45.51	"	"	93.8
44.79	44.85	5	44.77	"	"	97.2
43.92		1	43.99	"	"	22001.4
42.80	42.89	1	42.83	1.24	"	06.9
41.68	41.79	1	41.70	"	"	12.0
41.24		1	41.25	"	"	14.4
† 40.92	40.99	5	40.90	"	"	16.0
40.72	40.79	5	40.70	"	"	16.9
39.95	39.99	2	39.96	"	"	20.7
† 35.87	35.99	6	35.95	"	"	40.5
35.30		3	35.36	"	"	43.3
	33.31			"	"	46.9
32.93		1		"	"	54.8
† 30.92	30.99	7	30.92	"	"	64.6
30.03	30.01	1	30.04	"	"	68.9
27.62	27.69	2	27.65	"	"	80.7
† 27.52		2	27.53	"	"	81.1
† 26.65	26.77	7	26.65	"	"	85.4
26.25		2		"	6.1	87.2
24.98	24.99	1	25.01	"	"	93.4
22.2		1b	22.18	"	"	22107.
† 21.31	21.35	3	21.30	"	"	11.3
† 15.60	15.66	1	15.60	"	"	39.2
14.6	14.67	1n	14.64	"	"	44.
† 12.06	12.16	4	12.05	"	"	56.4
10.17		1n		"	"	66.0
† 07.00	07.11	2	07.00	"	"	81.4
03.2		1b		1.23	"	22200.
01.93	02.07	1	01.92	"	"	06.3
† 01.25	01.30	3	01.24	"	"	09.4
00.44	00.49	3	00.42	"	"	13.9
† 4498.87		2	4498.87	"	"	21.7
† 97.02	97.05	6	97.02	"	6.2	30.8

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Previous Observations (Hasselberg *)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney			$\lambda +$	$\frac{1}{\lambda} -$	
4495.46	4595.53	1	4495.42	12.3	6.2	22238.4
† 92.49	92.45	3	92.45	"	"	53.3
‡ 92.00	91.93	2n	91.99	"	"	55.9
			91.81	"	"	
† 89.60	89.66	2	89.60	"	"	62.4
		2	88.18	"	"	74.4
	83.07	2	83.01	"	"	22300.0
		1	81.57	"	"	07.3
† 80.47	80.45	1	80.40	"	"	13.0
		1		"	"	13.1
† 75.51	76.51	1b	75.47	"	"	37.7
† 73.90		1	73.91	"	"	45.7
		1	67.72	1.22	"	76.6
		ln	66.33	"	"	83.4
		ln		"	"	85.3
† 65.49	65.55	2	65.54	"	"	87.8
		1	65.08	"	"	89.9
		1	64.84	"	"	91.2
		1	62.98	"	"	22400.6
† 60.8		1b	60.95	"	"	11.
† 59.87	59.99	2	59.95	"	"	15.7
	58.81	4	58.75	"	"	21.6
	55.27			"	"	39.1
† 43.87		1	43.90	"	"	96.3
† 42.44		1	42.43	"	"	22504.0
		1		"	"	46.4
		ln	32.93	"	"	52.1
† 32.33	32.41	2	32.30	"	"	56.
† 30.63		2	30.59	1.21	6.3	63.8
		1	30.07	"	"	66.7
† 28.75		1	28.71	"	"	73.4
		1	25.27	"	"	91.1
† 24.46	24.51	3	24.40	"	"	95.2
† 23.50		1	23.46	"	"	22600.2
		2n	22.84	"	"	03.5
		1b		"	"	08.
		ln	21.12	"	"	12.3
† 14.03	4414.02	2	14.00	"	"	48.8
	12.96	1		"	"	53.7
† 12.43	12.49	1	12.42	"	"	56.8
† 11.28	11.21	1	11.26	"	"	63.0
	11.21	ln	11.15	"	"	63.3
	10.44	1	10.47	"	"	67.0
	09.94	ln		"	"	70.3
		ln		"	"	80.1
		ln		"	"	85.5
		ln	06.45	"	"	87.7
	03.68	2	03.68	"	"	22702.0
		2n	03.55	"	"	02.5
† 00.00		ln	4399.97	"	"	21.0
4397.44		1	97.40	"	"	34.2
		1	95.58	"	"	43.6
† 93.7		1b	93.66	1.20	"	54.
† 91.94		3	91.90	"	"	62.7
		ln		"	"	06.5

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Previous Observations (Hasselberg *)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adency			$\lambda +$	$\frac{1}{\lambda} -$	
† 4387·67	4387·73	2	4387·64	1·20	6·3	22784·7
† 85·16		1	85·11	"	"	97·9
	84·19			"	"	22802·9
83·03	83·16	1	83·04	"	"	08·6
82·73		1n		"	"	10·5
† 81·30	81·39	2	81·25	"	"	17·7
80·8		1b	80·73	"	"	21·
79·97		1	79·93	"	"	24·9
78·50		1n		"	"	32·6
† 77·71	77·79	1	77·73	"	"	36·5
76·95	77·04	2	76·95	"	"	40·4
76·50		1n		"	"	43·0
† 75·49	75·54	3	75·52	"	"	53·4
† 74·33	74·37	4	74·34	"	"	54·2
† 73·82		1	73·83	"	"	57·0
73·43	73·49	2	73·41	"	"	58·9
71·48	71·50	7	71·44	"	"	69·2
71·1		1b		"	"	71·
69·07		1		"	"	81·9
68·40		1	68·42	"	6·4	85·3
67·75		1n		"	"	88·7
66·57		1n		"	"	94·9
65·00		1		"	"	22903·1
64·3		1n		"	"	07·
† 63·29	63·35	3n	63·25	"	"	11·9
† 59·80	4359·83	7	59·78	"	"	30·4
† 57·68		1	57·70	"	"	41·6
† 56·93		1	56·91	1·19	"	45·5
56·44		1		"	"	48·1
54·10		1		"	"	60·5
† 51·99	52·01	10	51·91	"	"	71·5
51·28	51·28	7r	51·20	"	"	75·3
47·67		1n		"	"	94·4
† 47·02	47·04	3	47·00	"	"	97·8
45·28		1		"	"	23007·1
† 44·73	44·74	10	44·66	"	"	10·0
43·37		1	43·32	"	"	17·2
42·2		1b		"	"	23·
41·30		1		"	"	28·2
40·33	40·29]	2	40·26	"	"	33·4
† 39·95	39·93	5	39·85	"	"	35·4
39·69	39·68	7	39·60	"	"	36·7
38·99		1	38·95	"	"	40·4
38·58		1	38·56	"	"	42·6
† 37·78	37·81	8	37·70	"	"	46·8
37·45		1	37·38	"	"	48·6
32·77		1	32·75	"	"	73·6
	27·38			"	"	23102·3
† 25·27	25·29	3	25·24	"	"	13·6
† 23·71	23·79	2	23·70	"	"	21·9
† 21·81		1	21·80	"	"	32·1
21·45		1	21·44	"	"	34·0
20·79		1	20·75	"	"	31·5
† 19·82		2	19·82	"	"	42·7
18·12		1		1·18	"	51·8

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuum
Exner and Haschek	Adeney			$\lambda +$	$\frac{1}{\lambda}$	
4315·7		1b		1·18	6·4	23165·
15·28		1		"	"	67·1
12·67	4312·68	1	4312·65	"	"	81·0
10·7		1n		"	"	92·
09·95		1		"	"	95·7
09·05	09·17	1n		"	"	23200·2
07·15	07·75	1n	07·65	"	6·5	09·1
† 05·67	05·55	1	05·61	"	"	19·0
02·96		1	02·95	"	"	33·3
† 01·38	01·44	3	01·33	"	"	41·7
00·70	00·60	2	00·68	"	"	45·8
00·44		1		"	"	46·9
† 00·17		1		"	"	48·4
† 4299·90	4299·95	1	4299·87	"	"	49·7
	99·80			"	"	50·4
98·1		1b		"	"	60·
† 97·90	97·80	4	97·91	"	"	61·0
† 97·24	97·16	2	97·21	"	"	64·5
96·83		1	96·81	"	"	66·5
96·51		1	96·47	"	"	68·2
95·92	95·82	4	95·92	"	"	71·7
93·75	93·62	1	93·73	"	"	83·5
† 92·15	92·16	2	92·14	"	"	91·8
† 89·92	89·96	15r	89·87	"	"	23303·8
88·57		1		"	"	11·3
85·06	85·08	1	84·99	"	"	30·3
† 84·90		1	84·84	"	"	31·3
84·37	84·43	4		"	"	34·0
† 83·17		1n		"	"	40·7
† 80·58	80·65	5	80·53	1·17	"	54·6
78·21		1		"	"	67·8
	† 77·29			"	"	72·8
76·12		1		"	"	79·2
75·73	75·86	3		"	"	81·0
† 74·99	75·00	20r	74·91	"	"	85·3
	74·15			"	"	90·0
73·82		1		"	"	91·8
73·11		2	73·04	"	"	95·6
71·24	71·24	2	71·18	"	"	23405·9
70·12	70·08	1	70·08	"	"	12·1
† 69·45	69·51	2		"	"	15·5
68·97	69·03	1	68·90	"	"	18·2
66·99	67·09	1	66·96	"	"	29·0
† 63·31	63·37	5	63·28	"	"	49·4
62·52		1	62·53	"	"	54·8
62·28		3n	62·27	"	"	55·3
62·12	62·10	4		"	"	56·0
61·79		1	61·77	"	"	57·8
† 61·51	61·54	2	61·49	"	"	59·3
59·35		1n		"	"	71·3
57·52		1		"	"	81·3
56·80		1n		"	"	85·3
56·30		1n		"	"	88·1
55·65	55·70	3	55·65	"	"	91·5
† 54·50	54·51	30r	54·49	"	"	98·0

CHROMIUM (SPARK SPECTRUM)--continued.

Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney			$\lambda +$	$\frac{1}{\lambda}$	
	4252.95					
	4252.78	3		1.17	6.6	23506.5
	52.40	1	4252.37	"	"	07.4
	48.85	1	48.84	"	"	09.5
†	48.48	1	48.47	"	"	29.2
	46.9	1b		"	"	31.2
	46.5	1b		"	"	40.
†	42.55	8		1.16	"	48.
	41.35	1		"	"	64.0
†	40.85	4	40.82	"	"	70.8
†	39.08	2	39.08	"	"	73.5
	37.85	1	37.83	"	"	83.4
	34.64	1	34.64	"	"	90.3
	33.38	2		"	"	23608.2
	33.05	1n	33.00	"	"	15.2
	32.36	1	32.35	"	"	16.7
	31.5	1b		"	"	20.9
	30.62	1n	30.61	"	"	26.
	† 26.76			"	"	30.6
	25.76			"	"	52.2
	25.06	4		"	"	57.8
†	24.67	2	24.64	"	"	61.9
	22.91	2	22.89	"	"	63.5
†	22.2	1n		"	"	73.4
†	21.74	3	21.71	"	"	78.
†	17.77	3	17.75	"	"	80.3
	17.3	1n		"	"	23702.5
†	16.50	2	16.50	"	"	05.
	15.9	1n		"	"	09.5
	14.33	1		"	"	13.
†	13.32	1	13.31	"	"	22.0
	12.82	1	12.77	"	"	27.6
				"	"	30.6
				"	"	32.2
†	11.54	2	11.47	"	"	37.8
†	09.92	2	09.90	"	"	46.8
	09.51	4	09.50	"	"	49.0
†	08.51	3	08.50	"	"	54.5
	07.52	1n		"	"	59.9
†	07.07	3	07.05	"	"	62.9
†	04.64	3	04.61	1.15	"	76.4
†	04.35	1	04.37	"	"	78.3
†	03.76	2	03.71	"	"	81.3
†	00.29	1	00.27	"	6.7	23800.9
†	4198.60	4	4198.65	"	"	10.3
	98.05	1n		"	"	13.9
†	97.40	4	97.38	"	"	17.7
	95.60	2		"	"	27.5
†	95.14	4	95.09	"	"	30.3
	94.50	1		"	"	34.0
†	93.87	4	93.80	"	"	37.5
	92.68			"	"	44.4
†	92.30	3	92.25	"	"	46.5
†	91.94	1	91.90	"	"	48.6
†	91.45	3	91.41	"	"	51.2
	90.90	1		"	"	54.5

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Previous Observations (Hasselberg *)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney			$\lambda +$	$\frac{1}{\lambda} -$	
† 4190·32		4	4190·32	1·15	6·7	23857·8
† 86·54	4186·41	2	86·50	"	"	79·7
85·8		1b		"	"	84·
† 85·53		1	85·50	"	"	85·1
85·07		2		"	"	87·8
84·83		1		"	"	89·1
83·24		1		"	"	98·2
81·9		1b		"	"	23906·
80·9		1b		"	"	12·
80·15		1		"	"	15·9
79·57		3		"	"	19·2
† 79·44	79·48	6	79·37	"	"	19·8
78·15		1n		"	"	27·3
76·83		1		"	"	34·9
† 76·11	76·14	2	76·09	"	"	38·9
75·41	75·39	2	75·34	"	"	43·1
† 75·01	75·03	6	74·98	"	"	45·4
74·4		1n		"	"	49·
74·1		1n		"	"	51·
† 72·99	72·96	4	72·88	"	"	57·0
† 72·15		1n		"	"	61·7
71·85		2	71·81	"	"	63·5
71·03		1		"	"	68·2
70·39	70·31	3	70·31	"	"	72·1
† 70·02	69·99	4	69·94	"	"	74·1
	69·69		69·67	"	"	75·9
† 65·71	65·67	5	65·67	1·14	"	98·9
† 63·80	63·79	6	63·76	"	"	24010·4
† 61·60	61·61	5	61·55	"	"	22·5
61·3		1n		"	"	24·
59·1		1b		"	"	37·
	54·65			"	"	62·6
† 53·99		5	53·96	"	"	68·8
53·25		1	53·20	"	"	70·8
† 52·94		3	52·89	"	"	72·6
51·7		1n		"	"	80·
51·18		1		"	"	82·8
† 49·65	49·55	1		"	"	92·0
47·8		1b		"	6·8	24102·
46·90		1	46·81	"	"	07·6
46·37		1		"	"	10·7
† 46·2		1n		"	"	12·
45·94	45·95	7		"	"	13·2
43·65		1n		"	"	26·5
† 42·36		2	42·31	"	"	34·0
40·9		1b		"	"	42·
† 39·3		1b		"	"	52·
38·15		1n		"	"	58·6
37·60		1		"	"	61·8
† 34·45	34·83	1		"	"	79·1
32·62		1		"	"	90·9
† 31·52	31·61	3	31·50	"	"	97·1
30·3		1b		1·13	"	24204·
29·4		1b		"	"	10·
† 28·45	28·71	2	28·53	"	"	14·6

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Previous Observations (Hasselberg *)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Addney			$\lambda +$	$\frac{1}{\lambda} -$	
4127·82	4127·91	2	4127·77	1·13	6·8	24218·8
27·47	27·46	2	27·44	"	"	21·2
27·16	27·14	1		"	"	23·0
† 27·09		1	27·05	"	"	23·3
† 26·67	26·74	5	26·67	"	"	25·6
26·25		1	26·25	"	"	28·3
25·63		ln		"	"	31·9
† 23·55	23·64	4	23·55	"	"	43·9
† 22·32	22·34	2	22·34	"	"	51·3
21·99	22·04	3	21·96	"	"	53·2
† 21·6	21·55	1b	21·41	"	"	56·
† 20·79	20·83	3	20·78	"	"	60·3
16·80		3		"	"	83·9
	15·08	ln		"	"	94·1
13·45		1		"	"	24303·7
12·85		1		"	"	07·2
† 11·19	11·26	4		"	"	16·8
† 09·87	09·87	2	09·74	"	"	24·9
† 08·58		1	08·54	"	"	32·5
06·23		1		"	"	46·4
† 05·06		2	04·90	"	"	53·4
04·51		1		"	"	56·7
04·00		1		"	"	59·7
† 01·35		1	01·31	"	"	75·4
00·00		1		"	"	83·4
† 4099·60		1		"	6·9	85·7
99·19		1	4099·16	"	"	88·2
† 98·59		2		"	"	91·7
95·10		1		"	"	24412·5
93·5		1b		1·14	"	22·
93·25		ln		"	"	23·6
† 92·37		1		"	"	28·8
† 90·50		2n	90·43	"	"	40·0
90·30		1b		"	"	41·2
89·75		1b		"	"	44·5
89·0		1b		"	"	49·
87·8		1b		"	"	56·
87·2		1b		"	"	60·
† 86·31		1		"	"	65·1
85·18		1	85·15	"	"	71·8
82·48	4082·69	2		"	"	87·4
82·03		1		"	"	90·7
† 81·9		ln	81·88	"	"	91·
† 80·41		1	80·35	"	"	24500·4
† 77·86	77·89	3	77·81	"	"	15·7
† 77·27		2	77·21	"	"	19·3
† 76·22	76·52	2	76·20	"	"	24·7
† 75·02		2	75·01	"	"	32·9
† 71·11	71·13	4n	71·13	"	"	56·4
† 68·00	67·91	1	67·94	"	"	75·5
67·09		4		"	"	80·7
† 65·89		4	65·84	"	"	88·0
64·74		1		"	"	94·9
	62·86			"	"	24606·3
	61·81			"	"	12·7

CHROMIUM (SPARK SPECTRUM)—*continued*.

Wave-length		Intensity and Character	Previous Observations (Hasselberg *)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney			$\lambda +$	$\frac{1}{\lambda} -$	
†4060·81		2	4060·77	1·14	6·9	24618·7
† 58·93	4058·98	6	58·89	"	"	30·0
57·35		1		"	"	39·7
† 56·97		1	56·93	"	"	42·0
† 56·22	56·30	3	56·17	"	"	46·3
† 54·27		3		"	"	58·4
† 52·16	52·04	3		"	"	71·7
51·50	51·59	2	51·47	"	"	75·1
50·22		1	50·18	"	7·0	83·0
49·95		1	49·90	"	"	84·7
49·31	49·38	3a		"	"	88·5
† 48·94	48·98	5	48·94	"	"	90·7
	47·35			1·11	"	24700·5
† 46·90		1	46·89	"	"	03·3
† 44·38	44·29	1	44·24	"	"	18·9
† 43·87		2	43·85	"	"	21·8
† 42·43		1	42·40	"	"	30·6
† 41·97		1		"	"	33·4
† 39·31	39·28	5r	39·21	"	"	49·8
38·20	38·22	5		"	"	56·4
37·80		1		"	"	59·0
† 37·45		1	37·43	"	"	61·1
35·3		1b		"	"	74·
34·10		1		"	"	81·7
33·45		1	33·44	"	"	85·7
† 33·16		1		"	"	87·4
31·31		1	31·26	"	"	98·8
† 30·86	30·90	3	30·82	"	"	24801·5
28·26		1	28·22	"	"	17·6
† 27·26	27·30	3	27·24	"	"	23·7
† 26·30	26·36	4	26·30	"	"	29·5
25·61		1	25·60	"	"	33·9
† 25·16	25·21	3	25·14	"	"	36·6
24·73	24·71	1		"	"	39·4
† 23·90	23·95	2	23·90	"	"	44·4
† 22·41	22·47	4	22·38	"	"	53·5
† 18·38		1	18·36	"	"	78·6
18·11		1		"	"	80·3
† 16·96		1	16·95	"	"	87·4
† 14·82	14·64	2		1·12	"	24901·3

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
†4012·68	4012·68	4012·62	7	4012·63	1·10	7·0	24914·1
11·11			1		"	"	23·8
07·7			1b		"	"	45·
04·87			1		"	"	62·6
† 04·06	04·01		1	04·11	"	"	67·8
03·48	03·50	03·47	5		"	"	71·2
02·63	02·48		1		"	"	77·0

CHROMIUM (SPARK SPECTRUM)—*continued*.

Exner and Haschek	Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Lohso			$\lambda +$	$\frac{1}{\lambda}$	
†4001·60	4001·61	4001·63	5	4001·58	1·10	7·0	24982·9
00·75			1		"	"	88·3
†3999·81	3999·86	3999·83	2	3999·85	"	7·1	93·9
99·00	98·96		1		"	"	99·3
† 94·10			2	94·10	"	"	25029·8
† 93·00	93·08	92·95	5	92·95	"	"	36·7
92·24			1		"	"	41·5
† 91·81	91·83	91·86	5	91·81	"	"	44·1
91·31	91·30	91·23	9	91·26	"	"	47·5
† 90·15	90·11	90·12	6r	90·14	"	"	54·8
		88·20			"	"	66·9
		87·72			"	"	69·9
† 84·50	84·51	84·50	5	84·48	"	"	90·1
84·08	84·05	84·06	7	84·02	"	"	92·9
83·36		83·36	1		"	"	97·3
82·10			1		"	"	25105·3
† 81·37	81·45	81·36	3	81·37	"	"	09·7
79·96			2n	79·99	"	"	18·8
† 79·65	79·72	79·65	4		"	"	20·6
† 78·89	78·87	78·83	3	78·81	"	"	25·7
† 76·82	76·80	76·84	9	76·81	"	"	38·6
† 72·81			1	72·85	1·09	"	64·0
† 71·39			3	71·39	"	"	73·0
† 69·93	69·85	69·91	9	68·89	"	"	82·5
69·16	69·15		3	69·20	"	"	87·2
68·60Ca	68·57	68·62	8		"	"	90·7
	† 66·45				"	"	25203·4
† 64·47			1		"	"	17·0
† 63·86	63·73	63·86	10	63·82	"	"	21·1
62·32			1		"	"	30·6
		62·07			"	"	32·2
† 60·88			1	60·95	"	"	39·8
		60·21			"	"	44·7
59·9			1b		"	"	46·
† 58·22			1		"	"	56·8
† 56·42			1		"	"	69·3
† 53·30			1	53·34	"	7·2	88·1
52·53			2	52·56	"	"	93·0
51·90			1	51·93	"	"	97·0
† 51·23			ln	51·26	"	"	25301·4
49·75			1b		"	"	10·9
† 49·00			1		"	"	15·7
	48·33				"	"	20·0
† 46·09		46·15	1	46·15	"	"	34·1
45·63			1	45·68	"	"	37·3
44·37			1		"	"	45·4
† 43·73			1		"	"	49·5
43·40			1		"	"	51·6
† 41·62	41·50	41·65	5r	41·66	"	"	63·0
41·28			1		"	"	65·3
40·40			ln		"	"	70·9
39·4			1b		"	"	77·
38·50		38·48	ln		"	"	83·2
		38·03			"	"	86·2
37·7			1b		"	"	88·

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adency	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
3936.23			1		1.09	7.2	25395.0
35.70			1n		"	"	25401.2
33.81Ca	3933.81	3933.79			1.08	"	18.5
29.9			1b		"	"	39.
		29.34			"	"	42.4
† 28.80	28.86	28.80	6	3928.79	"	"	45.7
† 26.81	26.91		3	26.80	"	"	57.8
	25.35	25.21			"	"	68.0
		24.84			"	"	71.5
23.49			1	23.51	"	"	80.3
	† 22.95				"	"	83.8
† 21.16	21.05	21.18	5	21.20	"	"	95.4
20.24			1	20.25	"	"	25501.4
† 19.32			8	19.31	"	"	07.4
	19.05				"	"	09.2
† 17.72		17.73	1	17.75	"	"	17.8
17.10			1	17.15	"	"	21.9
† 16.37	16.30	16.40	4	16.38	"	"	26.7
† 16.00	16.03	16.00	3	15.96	"	"	29.0
† 15.64	15.83	15.67	1	15.65	"	"	31.3
† 14.47	14.29	14.47	2	14.45	"	"	39.0
† 12.50		12.50	1n		"	"	51.9
		12.07			"	"	54.7
11.47			1		"	"	58.6
10.90			1		"	"	62.4
† 08.90	08.89	08.91	6r	08.87	"	7.3	75.3
07.92			2	07.91	"	"	81.8
† 07.44			1	07.40	"	"	84.9
† 05.80	05.78	05.79	6		"	"	95.7
		05.30			"	"	98.9
† 03.32	03.31		2	03.30	"	"	25612.0
03.04	03.03		4	03.02	"	"	13.8
02.23		02.24	2	02.22	"	"	19.1
† 3897.80	3897.91	3897.73	2n	3897.83	"	"	48.0
95.32			1n		1.07	"	64.5
† 94.75			1		"	"	68.3
† 94.20	94.16	94.16	4	94.20	"	"	72.3
† 92.2			1b		"	"	85.
92.07	92.08		2	92.07	"	"	85.9
† 90.97	90.96		2		"	"	93.3
90.33			1		"	"	97.5
88.42			1		"	"	25710.2
† 86.93	86.96		4	86.94	"	"	19.8
† 85.35	85.35	85.33	5	85.35	"	"	30.5
† 83.83		83.76	1	83.78	"	"	40.7
83.44	83.45		5	83.41	"	"	43.0
82.02			1		"	"	52.5
† 81.40		81.36	2n	81.37	"	"	56.7
80.52			1		"	"	62.4
† 79.38	79.39	79.35	3n	79.39	"	"	70.1
78.47			1		"	"	76.1
† 77.50			1n		"	"	82.5
77.27			1		"	"	84.0
77.10			1		"	"	85.2
	75.73				"	"	94.3

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
† 3875.4	3875.41		1b		1.07	7.3	25796.4
† 74.75			2n		"	"	25800.8
	74.55				"	"	02.1
73.7			1b		"	"	07.
71.7			1b		"	"	21.
† 70.4			1b		"	"	30.
† 68.43			1	3868.41	"	"	43.0
66.68		3866.67	1		"	"	54.7
66.20			1		"	"	57.9
		66.07			"	"	58.8
† 65.74			6	65.73	"	"	61.0
	64.69				"	"	68.0
		64.24			"	"	71.0
† 62.71			1		"	"	81.3
† 60.1			1b		"	"	99.
† 59.1			1b		"	"	25905.
† 57.78	57.77	57.79	4	57.74	"	"	14.3
† 56.45	56.46		2	56.40	1.06	"	23.3
† 55.73	55.74	55.75	3	55.75	"	"	28.1
† 55.44	55.41	55.42	2	55.41	"	"	30.2
54.97	54.95		ln		"	"	33.2
† 54.39	54.38	54.36	4	54.36	"	"	37.1
† 53.46			1		"	"	43.4
52.72	52.69		1		"	"	48.5
† 52.36	52.30	52.33	2	52.33	"	"	51.0
† 50.18	50.19		5r	50.13	"	"	65.6
49.67	49.66		3	49.66	"	"	69.0
† 49.50	49.53	49.55	3		"	"	69.9
† 49.14	49.01	49.13	4	49.15	"	"	72.6
47.7			1b		"	"	82.
45.8			ln		"	"	95.
42.21			1		"	"	26020.1
† 41.42	41.42		5n	41.42	"	"	24.7
36.70			1		"	"	56.8
	† 36.23			36.22	"	"	60.0
† 34.87	34.86	34.88	2	34.88	"	"	69.2
† 33.63			1	33.62	"	"	77.6
33.3			ln		"	"	80.
32.92			1		"	"	82.5
32.47			1		"	"	85.5
31.8			ln		"	"	90.
† 31.18	31.16		2	31.15	"	"	94.4
† 30.20	30.18	30.14	4n	30.17	"	"	26101.2
† 26.60	26.64	26.59	3	26.55	"	"	25.5
† 25.56	25.60	25.55	2	25.54	"	"	32.6
† 23.66	23.73		2	23.64	"	"	45.4
22.25			1	22.22	"	"	55.3
† 21.74	21.78		1	21.71	"	"	58.8
† 21.03	21.01		1	21.00	"	"	63.7
	† 20.71				"	"	65.8
20.13			1	20.11	"	"	69.8
† 19.72	19.83		4	19.68	"	"	72.3
† 18.62	18.71	18.60	3	18.61	"	"	80.0
† 17.99	17.98		2	17.97	"	7.4	84.4
† 16.34	16.38		3	16.30	1.05	"	95.0

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
	3815·83				1·05	7·4	26199·2
† 3815·56	15·61	3815·60	4	3815·53	"	"	26200·9
† 14·77	14·81		3	14·74	"	"	06·3
	14·21		3		"	"	10·7
† 12·42	12·46		3	12·37	"	"	22·5
	10·91		1		"	"	33·0
† 09·65	09·74		2		"	"	41·4
		08·46			"	"	49·9
† 08·06	08·15	08·06	3	08·06	"	"	52·5
† 06·96	07·07		3	06·97	"	"	59·9
† 06·70			1	06·68	"	"	62·1
† 04·99	05·04	04·94	7	04·91	"	"	73·9
† 01·37			2n		"	"	98·9
† 3797·87	3797·85		5r	3797·85	"	"	26323·2
† 97·27	97·29		4	97·28	"	"	27·2
† 94·74	94·77		3	94·75	"	"	44·8
† 94·01	94·03		4	94·02	"	"	49·9
† 93·44	93·45		4	93·46	"	"	53·9
† 92·27	92·31		4	92·30	"	"	62·0
† 91·51	91·52		4	91·51	"	"	67·3
† 90·61	90·58		3	90·61	"	"	73·7
	90·38		1	90·36	"	"	75·2
	89·85		1	89·87	"	"	78·9
† 88·99	88·91		3	89·00	"	"	85·1
		3788·40			"	"	89·0
88·1			ln		"	"	91·
		87·86			"	"	92·7
		87·29			"	"	96·7
86·38			1	86·38	"	"	26403·1
		84·77			"	"	14·3
		84·02			"	"	19·5
83·85			ln		"	"	20·7
	83·33	83·43			"	"	24·1
82·6			1b		"	"	29·
		82·29			"	"	31·6
80·9			1b		"	"	41·
		80·57			"	"	43·6
80·3			1b		"	"	45·
		† 79·85			"	"	48·7
		78·99			"	"	54·7
† 78·81			1		"	"	56·0
77·48			1		"	"	65·3
76·4			1b		1·04	"	73·
74·9			1b		"	"	83·
69·12			1	69·13	"	7·5	26523·9
68·86	68·92		2	68·85	"	"	25·5
† 68·37	68·44		5	68·37	"	"	29·0
† 67·57	67·61		1	67·56	"	"	34·7
66·80			ln		"	"	39·7
† 65·72	65·69		ln		"	"	48·0
65·47	65·46		ln		"	"	49·6
† 64·8			1b		"	"	54·
62·02	62·05		ln		"	"	73·9
† 61·90		61·85	ln		"	"	75·0
61·53			1		"	"	77·1

CHROMIUM (SPARK SPECTRUM)—*continued.*

Exner and Haschek	Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
3758.20	3758.19	3758.35	3	3758.14	1.04	7.5	26599.9
† 57.82	57.82		5	57.80	"	"	26601.0
† 57.34	57.36		2	57.28	"	"	03.6
56.71			1		"	"	07.0
55.99			1	55.97	"	"	11.5
55.30			1		"	"	16.6
† 54.75	54.68	54.87	5		"	"	21.5
50.75	50.79		3		"	"	25.3
† 49.18	49.18		5r	49.13	"	"	53.6
48.81	48.78		4	48.73	"	"	65.0
		47.79			"	"	67.8
† 47.42	47.46		2	47.40	"	"	74.9
† 47.08			1		"	"	77.4
† 44.64	44.70		3	44.63	"	"	80.0
† 44.10	44.09		6	44.01	"	"	97.1
† 43.72	43.74		5	43.67	"	"	26701.2
43.13	43.19		3	43.08	"	"	03.8
42.25			1		"	"	07.9
		40.67			"	"	14.4
38.58			5r		"	"	25.7
37.70	37.54	37.42	2		1.03	"	40.6
36.58			ln		"	"	48.1
36.05		36.09	ln		"	"	54.9
34.7		34.63	lb		"	"	59.0
34.00		34.05	l		"	"	68.7
		33.13			"	"	73.2
32.19	32.24	32.16	3	32.15	"	"	79.7
† 31.87			1		"	"	86.4
† 30.94	31.01	30.96	3	30.91	"	"	88.7
27.49			3		"	"	95.2
26.05			1		"	7.6	26820.8
23.52	23.78		2		"	"	30.5
† 23.20			1		"	"	47.8
22.97			1		"	"	51.0
19.60			1		"	"	52.7
18.75	18.45		1		"	"	77.0
† 17.8	17.45		lb		"	"	84.2
† 16.70	16.75		ln	16.65	"	"	91.3
15.63	15.65	15.56	6		"	"	97.8
† 15.38	15.45	15.33	6		"	"	26905.9
13.14	13.20	13.11	9		"	"	07.5
11.45	11.61		2		"	"	23.7
10.70	10.41		1		"	"	35.5
10.25	10.41		ln		"	"	42.5
07.28			ln		"	"	44.2
† 07.1			lb		"	"	66.4
06.2			lb		"	"	68.
04.9			lb		"	"	74.
02.05			l		"	"	84.
† 3698.13	3698.20	3698.16	5		"	"	27004.5
† 96.90	96.96	96.95	2		1.02	"	33.1
96.01			1	3693.02	"	"	41.8
95.13			1		"	"	48.6
94.20			1		"	"	55.0
					"	"	61.9

CHROMIUM (SPARK SPECTRUM)—*continued*.

Wave-length			Intensity and Character	Previous Observations Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
3693.25			1		10.2	7.6	27068.8
† 89.77	3689.87		1	3689.76	"	"	94.0
89.45	89.57		1		"	"	96.3
88.58	88.47	3688.61	2	88.56	"	"	27103.3
† 88.25			1	88.24	"	"	05.5
† 87.5			3b	87.65	"	"	11.
† 86.84	86.89	86.85	4r	86.95	"	"	15.9
† 85.74	85.73	85.72	2	85.70	"	"	24.0
† 85.3			1n		"	"	27.
85.1			1n		"	"	29.
† 84.39	84.46		5		"	"	33.7
† 83.79	83.61		1	83.60	"	7.7	38.9
81.86	81.71		2	81.81	"	"	53.0
81.15	81.07	81.20	1	81.12	"	"	57.8
80.32			1	80.34	"	"	63.8
† 79.99	79.96		1	79.93	"	"	66.4
† 79.22	79.26		1	79.20	"	"	71.8
† 78.05	78.06	77.95	8	78.00	"	"	80.8
† 77.83	77.88		6		"	"	82.1
76.46	76.51		3		"	"	92.4
76.25			1n		"	"	93.9
74.3			1b		"	"	27208.
73.8			1b		"	"	12.
† 68.20	68.10	68.14	2n	68.17	"	"	54.0
† 66.82	66.87	66.81	3	66.78	"	"	63.8
† 66.30	66.39	66.23	1	66.30	"	"	67.7
66.15	66.19		2	66.10	"	"	68.7
† 65.10	65.17	65.09	6		"	"	76.5
† 63.39	63.42	63.39	3	63.35	"	"	89.3
† 63.03		62.97	1	62.97	"	"	92.1
61.60	61.64		1n		"	"	27302.6
61.40			1n		"	"	04.3
† 58.33	58.39	58.31	4		"	"	27.1
† 56.41	56.44	56.42	5r	56.36	1.01	"	41.4
† 54.09	54.14	54.07	4	54.05	"	"	58.8
† 51.83	51.89		3		"	"	75.8
† 50.50	50.56	50.48	5		"	"	85.7
50.0			1n		"	"	90.
† 49.8			1n		"	"	91.
† 49.14	49.18	49.16	4r	49.12	"	"	95.9
† 48.70	48.76	48.69	2	48.65	"	"	99.2
	48.31				"	"	27402.2
† 47.54	47.56		2		"	"	08.0
† 46.85			1		"	"	13.2
46.31	46.39		2	46.26	"	"	17.0
45.73	45.84		1		"	"	21.2
† 44.86	44.87	44.73	3		"	"	28.5
43.35		43.34	3		"	"	39.6
42.01		41.99	4r	41.95	"	"	49.7
† 41.65	41.73	41.62	2	41.61	"	"	52.3
	40.63				"	"	60.1
† 40.00	39.95	39.97	7	39.93	"	"	65.0
	38.89				"	7.8	73.1
38.5			1b		"	"	76.
38.00			1		"	"	79.8

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
†3636·75	3636·73	3636·75	5r	3636·72	1·01	7·8	27489·3
35·44	35·48		1		"	"	99·1
35·17	35·13		1	35·00	"	"	27501·2
	34·78				"	"	04·2
34·19	34·17		2		"	"	08·7
† 33·00	32·93	33·01	4	32·92	"	"	17·8
† 31·86	31·85		6		"	"	26·0
29·57	29·66		ln		"	"	42·6
28·2	28·26		1b		"	"	53·8
26·40	26·29	26·45	ln		"	"	67·9
20·2			ln		"	"	27615·
† 19·61	19·55		2		"	"	19·7
† 17·45	17·50		2		1·00	"	35·8
† 15·80	15·79		2	15·76	"	"	48·6
	14·41		1		"	"	59·2
† 13·82			1	13·78	"	"	63·8
† 13·35	13·34		6		"	"	67·4
† 12·76	12·76	12·76	3	12·70	"	"	71·9
	10·22		2	10·17	"	"	91·5
† 09·64	09·64	09·60	2	09·62	"	"	95·9
	08·77		1		"	"	27702·5
† 08·55	08·56		2	08·52	"	"	04·1
† 05·47	05·48	05·50	10	05·46	"	"	27·7
	04·70		1		"	"	33·8
† 03·90		03·91	9	03·86	"	"	39·9
02·73	02·78		1	02·68	"	"	48·7
		02·25			"	"	52·6
† 01·80	01·85		4	01·76	"	"	55·9
		00·53			"	"	65·8
†3599·55	3599·54		2	3599·51	"	"	73·5
	97·79				"	"	87·0
		3596·98			"	"	93·3
	94·47		1		"	7·9	27812·6
† 93·64	93·62	93·63	10	93·57	"	"	19·1
			1b		"	"	45·
			1b		"	"	53·
			ln		"	"	59·2
	87·42				"	"	07·3
	85·73		7		"	"	81·2
† 85·48	85·53	85·48	7	85·45	"	"	82·4
	85·33				"	"	89·8
	84·5		4b	84·45	"	"	97·5
	83·54				"	"	27903·3
† 82·79			1	82·74	"	"	07·
			ln		"	"	10·0
			ln		"	"	34·2
† 78·83	78·84		10	78·81	"	"	46·1
	77·30				0·99	"	52·9
	76·43		1		"	"	64·4
	75·0	74·91	5n		"	"	67·0
† 74·7	74·56		ln		"	"	70·3
	74·20	74·24	2	74·19	"	"	73·4
	† 73·81			73·79	"	"	77·4
† 73·30		73·52	3		"	"	80·1
† 72·91	73·00		2	72·90	"	"	86·0
† 72·20			1		"	"	

1906.

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CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda}$	
3571.52			1		0.99	7.9	27991.4
69.32			1	3569.28	"	"	28009.4
67.7			1b		"	"	21.
66.25	3566.34		3b	66.23	"	"	32.4
	65.54			65.31	"	"	38.3
65.12			1		"	"	41.6
64.91	64.94		1	64.87	"	"	43.3
64.45			1	64.44	"	"	46.9
64.09	64.14	3563.99	2		"	"	49.8
62.60	62.64		1	62.57	"	"	61.3
62.47			1	62.40	"	"	62.5
60.6			ln		"	"	77.
59.93			1	59.90	"	"	82.5
58.8	58.83		3b	58.74	"	"	91.3
56.28			1	56.27	"	"	28111.4
55.98			1	55.88	"	"	13.7
55.77			1				15.4
54.12			1	54.10	"	"	28.5
52.8	52.87		2b	52.85	"	"	38.4
50.80	50.82		3	50.73	"	8.0	54.6
49.0	48.97	48.95	1b	48.95	"	"	68.9
48.0			1b		"	"	77.
47.26			1		"	"	82.8
39.10			1		"	"	28247.8
37.36			1		0.98	"	61.7
36.6			1b		"	"	68.
33.02			1	33.04	"	"	96.4
31.60			1		"	"	28307.8
31.20			1		"	"	11.0
29.83			1		"	"	22.0
27.25	27.44		1	27.22	"	"	42.7
25.6			1b		"	"	56.
24.75			ln		"	"	62.8
23.8			1b		"	"	70.
23.12			ln		"	"	75.9
22.30	22.43		2		"	"	82.5
21.69			1		"	"	87.4
19.7			1b		"	"	28403.
18.77			1		"	"	11.0
18.51			1		"	"	13.1
13.17	13.24		2		"	"	56.3
12.00	11.94	11.90	6	11.93	"	"	66.2
10.67	10.64	10.66	3	10.66	"	8.1	76.6
08.98			ln		"	"	90.1
08.24			1		"	"	96.2
07.4			1b		"	"	28503.
06.72			ln		"	"	08.6
03.52	03.58		1		"	"	34.4
02.49	02.43		1		"	"	43.0
3495.71	3495.80		3		0.97	"	98.4
95.55	95.58	3495.53	4		"	"	99.7
95.13	95.13		2	3495.08	"	"	28603.1
	94.53				"	"	08.1
94.28			1		"	"	10.1
		92.37			"	"	25.8

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
†3489.58			ln		0.97	8.1	28648.6
89.25			ln		"	"	51.4
88.58	3488.66		l	3488.60	"	"	56.5
86.62			l		"	"	73.0
84.30	84.35	3484.29	4		"	"	92.0
		83.27			"	"	28700.6
82.75	82.48		2		"	"	04.8
	82.03				"	"	10.8
81.67	81.73		3	81.66	"	"	13.5
81.43	81.41		3	81.41	"	"	15.7
80.48			l		"	"	23.6
79.27			ln		"	"	33.6
78.89			l		"	"	37.5
78.30			l		"	"	41.6
77.32			ln		"	"	49.7
75.29	75.31		4		"	"	66.4
74.52	74.53		l		"	"	72.8
73.76	73.81		l		"	"	79.0
73.06	73.01		l		"	"	85.2
72.92			l		"	"	86.1
72.22	72.31		6		"	"	91.5
71.63			l		"	"	96.8
70.66	70.66		l		"	8.2	28804.7
70.53			l		"	"	05.8
69.72	69.76		l		"	"	12.4
68.87	68.96		l		"	"	19.3
67.85	67.86		2	67.86	"	"	28.1
67.15	67.21		2n		"	"	33.7
66.44			ln		"	"	39.8
65.73			l		"	"	45.8
65.38	65.36		2	65.40	"	"	48.8
64.99			l		"	"	51.9
64.17	64.06		l		"	"	59.2
63.8	63.66		lb		"	"	62.4
62.87			l		"	"	69.5
61.45			ln		"	"	81.4
60.57	60.46		l	60.60	"	"	89.2
59.41	59.41		5		"	"	98.4
58.22	58.21		l		0.96	"	28908.5
57.80	57.76		7		"	"	12.1
55.72	55.76		3	55.76	"	"	29.2
55.14	55.13		6		"	"	34.2
53.99			l		"	"	43.8
53.87			l		"	"	44.8
53.46	53.46		5	53.46	"	"	48.3
51.00	51.00		l		"	"	68.9
49.45			lb		"	"	81.9
47.89			2	47.90	"	"	95.0
47.56	47.58		3	47.55	"	"	97.8
47.15	47.23		2	47.15	"	"	29000.9
45.75	45.60		4r	45.71	"	"	13.7
45.25			2n		"	"	17.3
	45.03				"	"	19.1
44.52	44.42		ln		"	"	23.8
43.95	43.80		2		"	"	28.9

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
3441.60	3441.43		4	3441.56	0.96	8.2	29048.8
41.27	41.12		2		"	"	51.6
40.88			1		"	"	54.0
39.46			1		"	"	66.1
38.12			1		"	"	77.5
36.87			1		"	"	88.0
36.31	36.16		4	36.31	"	"	93.4
35.95			1		"	"	95.8
35.81	35.83		1		"	"	96.9
	34.88				"	"	29104.9
34.24	34.12		3		"	"	10.8
33.73	33.74		5n	33.72	"	"	14.6
33.50	33.44		10	33.42	"	"	18.8
32.47			1		"	8.3	25.2
32.17			1		"	"	27.8
31.82			1		"	"	30.8
31.42			1		"	"	34.1
30.58	30.51		1		"	"	41.6
30.03			1n		"	"	46.0
29.07	28.94		2		"	"	54.7
	28.88				"	"	55.7
27.85			1n		"	"	64.5
26.29	26.21		2		"	"	78.1
24.77			1		"	"	90.7
22.92	22.86		10		"	"	29206.5
21.8			3n		"	"	16.
	21.58				"	"	18.0
21.40	21.36		10		"	"	19.7
19.45			1n		"	"	36.2
17.90			1n		0.95	"	49.4
15.55			1n		"	"	69.6
12.35			1n		"	"	97.0
	11.83				"	"	29301.5
11.1			1b		"	"	08.
10.66	10.71		1		"	"	11.3
08.91	08.91		10		"	"	26.6
07.32			1		"	"	40.3
06.9			1n		"	"	44.
05.4			1b		"	"	57.
03.47	03.43		10		"	"	73.6
02.58	02.58		6		"	"	81.1
00.13			1n		"	"	29402.3
3399.65	3399.49		4		"	"	07.2
95.72	95.76		5		"	8.4	40.3
94.49	94.45		8		"	"	51.3
94.00	93.99		8		"	"	55.4
	93.71				"	"	57.9
93.18			8		"	"	62.5
91.58	91.50		8		"	"	76.7
90.87			1		"	"	82.6
88.90			1n		"	"	99.7
88.07			1		"	"	29506.9
87.82			1		"	"	09.1
86.74			1b		"	"	19.
86.30			1		"	"	22.4

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda}$	
3386.20			1		0.95	8.4	29523.2
85.45			1		"	"	29.8
84.79			1		"	"	35.5
82.82	3382.77		9		"	"	52.9
79.99	79.95		9		"	"	77.6
79.50	79.50		6		"	"	81.8
78.49	78.46		8		"	"	90.7
77.47			1		0.91	"	99.5
76.8			1b		"	"	29605
76.49	76.45		1		"	"	08.3
76.36			1		"	"	09.3
75.08	75.12		2		"	"	20.3
72.26	72.32		3		"	"	45.0
71.60			1n		"	"	51.1
70.3			1n		"	"	62
69.20	69.20		4		"	"	72.2
08.83	68.90		3		"	"	75.2
08.20	68.20		10		"	"	81.0
07.52	67.60		4		"	"	86.7
64.75			1b ^v		"	"	29711.5
63.85	63.87		4		"	"	19.3
61.92	61.96		6		"	"	36.3
60.48	60.48		10		"	8.5	49.1
58.64	58.62		9		"	"	65.5
57.52	57.51		6		"	"	75.4
56.0			1b		"	"	89
55.33			1n		"	"	94.8
53.25	53.26		5		"	"	29813.3
52.10	52.10		1		"	"	23.5
51.71	51.65		1		"	"	27.3
	50.19				"	"	40.6
	49.82				"	"	43.8
49.47	49.62		3		"	"	46.3
49.18	49.16		1		"	"	49.6
48.00	47.97		6		"	"	60.2
46.86	46.83		2		"	"	70.4
46.14	46.11		2		"	"	76.8
45.55			1		"	"	81.9
44.64	44.63		1		"	"	90.1
43.47	43.49		1		"	"	29900.5
42.78	42.71		10		"	"	07.0
42.13			1		"	"	12.5
40.03	39.91		10		"	"	31.9
39.3	39.11		2b		"	"	38.7
37.15	37.10		1		0.93	"	57.4
36.49	36.45		8		"	"	63.3
36.06			1		"	"	67.0
35.52	35.45		9		"	"	72.1
33.1	33.00		1b		"	"	94.0
33.03	33.00		1		"	"	94.4
32.3			1b		"	"	30 01
29.63			1n		"	"	24.9
29.16			1		"	"	29.1
28.50	28.49		4		"	"	35.1
26.72	26.73		1		"	"	51.1

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
3324.52	3324.47		7		0.93	8.6	30071.1
24.27			6		"	"	73.2
23.68	23.68		2		"	"	78.5
22.84	22.86		2		"	"	86.1
21.5			1b		"	"	98.
16.64	16.62		1		"	"	30142.5
15.46	15.42		1		"	"	53.3
14.72	14.68		4r		"	"	60.0
14.21	14.19		3d		"	"	64.6
13.23	13.19		3		"	"	73.6
12.35	12.31		6		"	"	81.6
12.10	12.04		6		"	"	84.0
10.86	10.80		6		"	"	95.3
10.1			1n		"	"	30202.
08.31	08.24		2		"	"	18.5
07.92	07.85		1		"	"	22.2
07.20	07.12		10		"	"	28.8
04.9			1n		"	"	49.
03.05			1		"	"	66.4
02.3			1b		"	"	73.
01.39	01.35		2		"	"	81.9
3298.9			1a		0.92	"	30304.
98.57	3298.50		1		"	"	07.9
98.42			1		"	"	09.0
95.58	95.55		9		"	"	35.2
95.15			1n		"	"	39.0
94.0			1n		"	"	50.
91.91	91.87		6		"	"	69.1
91.4			1n		"	"	74.
88.18	88.18		2		"	8.7	30403.3
86.09	86.09		3		"	"	22.6
83.19	83.17		3		"	"	49.6
79.66			1		"	"	82.3
76.07	76.06		1		"	"	30515.7
74.1			1n		"	"	34.
73.4			1b		"	"	41.
73.00	73.06		1		"	"	44.0
71.15			1n		"	"	61.6
70.28	70.28		5		"	"	69.7
69.87	69.95		3		"	"	73.2
69.72			4		"	"	75.0
	69.23				"	"	79.6
68.57			1		"	"	85.7
66.40	66.42		1		"	"	30605.9
64.40	64.40		4		"	"	24.8
	61.81				"	"	49.1
	60.81				"	"	58.5
60.10	60.05		2		"	"	65.4
58.88	58.89		3		0.91	"	76.6
57.92	57.91		2		"	"	85.8
55.41	55.41		2		"	"	30709.4
52.59	52.57		3		"	8.8	36.0
51.96	51.92		2		"	"	42.1
51.80	51.82		1		"	"	43.3
50.95	50.83		1		"	"	52.0

CHROMIUM (SPARK SPECTRUM)—*continued.*

Exner and Haschek	Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Lohse			$\lambda +$	$\lambda -$	
3250.74			1		0.91	8.8	30753.4
49.64	3249.62		1		"	"	63.9
47.65	47.61		1		"	"	82.9
47.45			1		"	"	84.6
47.15			ln		"	"	87.4
45.65	45.65		2		"	"	30801.7
45.40			1		"	"	04.0
	44.30				"	"	14.5
41.52			1		"	"	40.9
40.18	40.25		1		"	"	53.3
38.90	38.88		9		"	"	66.0
38.05			ln		"	"	68.3
38.20	38.19		1		"	"	72.6
37.85	37.82		1		"	"	76.0
37.46			1		"	"	79.6
35.36	35.30		ln		"	"	99.9
34.20	34.15		9		"	"	30911.0
31.75	31.76		1		"	"	34.1
30.95			ln		"	"	41.8
30.01	30.00		1		"	"	50.9
29.48	29.39		1		"	"	56.4
29.32			1		"	"	57.5
26.46	26.45		ln		"	"	85.0
25.50	25.50		3		"	"	94.1
19.90	19.83		2		0.90	"	31048.4
19.73			1		"	"	49.7
19.23	19.26		3		"	"	54.4
17.51	17.55		9		"	"	70.9
16.61	16.66		6		"	"	79.6
12.98	12.98		3		"	8.9	31114.8
12.59	12.64		3		"	"	18.4
11.63	11.57		2		"	"	28.2
11.42	11.45		1		"	"	29.8
	09.87				"	"	45.0
09.30	09.32		9		"	"	50.4
08.70	08.72		4		"	"	56.3
08.10	08.10		1		"	"	62.2
06.15			ln		"	"	81.1
05.23	05.23		3		"	"	90.1
03.67	03.66		2		"	"	31205.3
02.64	02.64		2		"	"	15.3
01.39	01.38		3		"	"	27.6
00.57	00.55		1		"	"	35.6
3199.97	3199.98		1		"	"	41.3
98.12	98.09		2		"	"	59.6
97.22			10		"	"	68.3
96.51			1		"	"	75.2
94.76	94.70		1		"	"	92.4
94.05			ln		"	"	99.3
	92.30				"	"	31316.5
90.8	90.68		ln		"	"	31.8
89.93	89.92		1		"	"	39.8
88.17	88.10		ln		"	"	67.4
86.85	86.82		2		"	"	70.2
84.56	84.43		2		"	"	93.2

CHROMIUM (SPARK SPECTRUM)—*continued.*

Exner and Hätschek	Wave-length		Intensity and Character	Previous Observa- tions (Hassel- berg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adency	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
3183.44	3183.42		5		0.90	8.9	31403.7
81.57	81.52		3		0.89	"	22.4
80.82	80.80		10		"	9.0	29.5
79.52			ln		"	"	42.3
78.83	78.87		ln		"	"	48.9
77.7			1b		"	"	60.
76.8			1b		"	"	69.
73.67	73.68		1		"	"	31500.2
72.20	72.21		4		"	"	14.8
69.33	69.33		3		"	"	43.4
68.49			1		"	"	51.8
64.5			1b		"	"	92.
64.03	63.92		{ 1		"	"	96.3
63.85			{ 1		"	"	98.1
62.56	62.54		2		"	"	31611.0
60.26	60.24		1		"	"	34.1
59.97	59.97		1		"	"	36.9
	59.78				"	"	38.8
59.22			1		"	"	44.4
58.14	58.14		2		"	"	55.2
55.24	55.31		1		"	"	84.0
	54.77				"	"	89.0
54.2	54.14		ln		"	"	95.1
53.7	53.71		ln		"	"	99.7
53.1	53.14		ln		"	"	31705.6
52.34	52.36		5		"	"	13.4
50.23	50.24		3		"	"	34.7
49.95	49.97		3		"	"	37.4
49.3			ln		"	"	44.
	48.88				"	"	48.3
48.56	48.62		1		"	"	51.2
47.33	47.34		7		"	"	63.9
45.86	45.92		2		"	9.1	78.4
45.21	45.24		2		"	"	85.1
	44.57				"	"	91.7
	44.25				"	"	95.0
44.0			ln		"	"	97.
43.85	43.83		ln		"	"	99.1
43.1	43.14		ln		"	"	31806.4
42.85	42.85		1		"	"	09.2
42.0			ln		"	"	18.
40.26	40.37		3		0.88	"	34.8
40.00	40.09		1		"	"	37.6
	39.55				"	"	42.6
38.38	38.37		1		"	"	54.5
37.68	37.64		1		"	"	61.8
37.25			1		"	"	66.0
36.81	36.84		7		"	"	70.3
35.86	35.91		3		"	"	79.8
35.46	35.48		3		"	"	84.0
34.43	34.50		3		"	"	94.3
32.20	32.19		10		"	"	31917.4
31.65			1		"	"	23.0
30.73	30.73		1		"	"	32.3
28.82	28.87		6		"	"	51.6

CHROMIUM (SPARK SPECTRUM)—*continued*.

Wave-length			Intensity and Character	Previous Observa- tions (Hassel- berg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
	3127·83				0·88	9·1	31961·4
	27·07				"	"	69·7
3125·6			2n		"	"	85·
25·12	25·17		10		"	"	89·4
22·73	22·72		4		"	"	32014·2
22·02	22·01		1		"	"	19·5
21·92			1		"	"	22·5
21·33	21·29		1		"	"	28·7
21·18			1		"	"	30·1
20·50	20·54		10		"	"	36·8
	19·90				"	"	43·2
	19·29				"	"	49·5
18·78	18·74		10		"	"	54·9
18·27	18·18		1		"	"	60·4
17·40	17·34		1		"	"	69·2
16·86	16·81		2		"	"	74·7
15·77	15·72		2		"	"	86·2
15·42	15·36		1		"	"	89·6
	14·48				"	9·2	98·9
13·77	13·69		ln		"	"	32116·9
12·10	12·05		1		"	"	23·7
11·0	11·00		1b		"	"	34·8
	09·43				"	"	51·0
08·77	08·75		1		"	"	58·0
07·70	07·64		3		"	"	69·2
	03·83				"	"	32209·1
03·60	03·54		2		"	"	11·8
	02·24				"	"	25·6
	3099·00				0·87	"	59·3
3098·27	98·22		ln		"	"	67·2
96·27	96·26		3		"	"	87·8
95·65	95·59		1		"	"	94·5
95·12	95·10		1		"	"	99·8
94·12	94·13		1		"	"	32310·1
93·61	93·62		4		"	"	15·4
88·01	88·08		1		"	"	73·7
85·50	85·52		ln		"	"	32400·4
84·58	84·61		ln		"	"	10·0
	83·82				"	9·3	18·0
83·27			ln		"	"	23·8
79·59	79·47		1		"	"	63·2
77·89	77·93		2		"	"	80·3
77·39			2		"	"	85·8
73·88	73·84		1		"	"	32523·1
73·40	73·44		1		"	"	27·7
72·57	72·63		1		"	"	35·4
71·7	71·75		ln		"	"	45·7
	71·12				"	"	52·1
67·27	67·35		1		"	"	92·5
65·18	65·05		1		"	"	32615·9
	64·36				"	"	23·9
63·92	63·93		1		"	"	28·6
	63·31				"	"	35·2
62·0			1b		0·86	"	49·
61·75	61·88		1		"	"	51·1

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observa- tions (Hassel- berg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
	3061.69				0.86	9.3	32652.4
3059.63	59.80		2		"	"	73.5
58.50	58.43		1		"	"	86.8
58.00	57.95		1		"	"	92.1
56.8	56.78		1b		"	"	32704.8
55.57	55.51		1		"	"	18.0
54.00	54.02		1		"	9.4	34.4
	52.32				"	"	57.6
	51.80				"	"	68.2
	50.87				"	"	68.1
50.23	50.25		8		"	"	74.9
49.7	49.51		1b		"	"	81.7
47.90	47.83		1		"	"	32800.5
47.77	47.82		1		"	"	01.2
	47.09				"	"	08.8
45.6	45.71		1b		"	"	24.3
44.30	44.29		1		"	"	38.9
43.99	43.97		1		"	"	42.3
42.90			1		"	"	59.0
41.85	41.89		5		"	"	65.1
41.03	41.05		7		"	"	74.1
40.4	40.39		1n		"	"	81.1
39.9	39.88		1n		"	"	86.5
38.15	38.15		1n		"	"	32905.4
	38.00				"	"	07.0
37.52			1		"	"	12.2
37.15	37.17		1		"	"	16.1
35.1	35.11		1n		"	"	38.4
34.64	34.62		1		"	"	43.5
34.30	34.31		1		"	"	47.1
34.22			1		"	"	48.0
33.05	33.07		2		"	"	60.6
31.49	31.48		1		"	"	77.7
30.37	30.39		2		"	"	89.8
29.28	29.29		1		"	"	33001.7
28.22	28.25		3		"	"	12.9
26.78	26.80		6r		"	"	28.9
24.46	24.48		2		"	9.5	54.1
21.68	21.67		2		0.85	"	84.7
20.77	20.79		1		"	"	94.5
18.91	18.96		1		"	"	33114.8
18.59	18.63		1		"	"	18.3
17.66	17.66		2		"	"	28.8
15.58	15.63		3		"	"	51.3
15.30	15.30		1		"	"	54.7
15.05			2		"	"	57.4
14.88			2		"	"	59.3
13.84	13.85		1		"	"	70.7
13.16	13.16		1		"	"	78.2
11.54	11.55		1		"	"	96.0
	11.22				"	"	99.6
10.72	10.75		1		"	"	33205.0
08.2	08.41		1b		"	"	31.8
05.16	05.18		1		"	"	66.5
	04.62				"	"	72.6

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
3003.98	3004.06		2		0.85	9.5	33279.2
01.00	01.01		1		"	"	33312.7
00.04	00.07		1		"	"	23.2
2999.37	2999.00		ln		"	"	32.9
98.88			1		"	"	36.3
	98.22		1		"	"	43.6
96.69	96.67		1		"	9.6	60.7
96.61			1		"	"	61.4
95.21	95.21		1		"	"	77.0
94.85	94.84		2		"	"	81.1
94.17	94.18		1		"	"	88.6
	93.65				"	"	94.4
93.2	93.16		1b		"	"	99.7
92.7			ln		"	"	33405
92.53	92.58		2		"	"	06.7
92.02	92.02		1		"	"	12.6
89.25	89.28		7		"	"	43.4
88.75	88.77		1		"	"	49.1
88.13	88.15		2		"	"	56.0
	87.61				"	"	62.0
	87.15				"	"	67.1
86.98			1		"	"	69.0
86.60			1		"	"	73.3
86.52			1		"	"	74.2
86.10	86.06		1		"	"	79.1
85.99			1		"	"	80.1
85.40			7		"	"	86.7
84.85	84.91		1		"	"	92.6
84.80			1		0.84	"	93.5
	83.00				"	"	33513.7
80.93			1		"	"	37.0
80.86	80.87		1		"	"	37.7
79.80	79.88		8		"	"	49.2
76.79	76.78		2		"	"	83.7
75.59	75.55		1		"	"	97.4
73.2	73.17		ln		"	"	33624.4
72.75	72.71		1		"	"	29.5
71.99	71.94		9		"	"	38.2
71.22	71.18		1		"	"	46.8
69.78	69.73		1		"	9.7	63.1
68.80	68.75		1		"	"	74.2
67.75			1		"	"	85.9
67.00	67.28		1		"	"	94.4
66.14	66.10		3		"	"	33704.4
63.58	63.52		1		"	"	33.6
61.81	61.80		4		"	"	53.5
60.00	60.04		1		"	"	73.8
59.66	59.68		1		"	"	77.9
	58.58				"	"	90.3
	58.14				"	"	95.3
57.67	57.67		ln		"	"	33800.7
57.4	57.36		ln		"	"	04.0
56.70	56.59		1		"	"	12.4
55.23	55.23		1		"	"	28.6
54.76	54.81		1		"	"	33.7

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum °		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
2953.79	2953.82		4		0.84	9.7	33844.9
53.46	53.44		3		"	"	49.1
52.57	52.61		1		"	"	58.9
52.10	52.08		1		"	"	64.6
51.52	51.50		1		"	"	71.3
50.8	50.83		ln		"	"	79.3
50.22	50.31		1		"	"	85.5
49.91	49.92		1		"	"	89.6
49.55	49.58		2		"	"	93.6
47.60	47.60		2		"	"	33916.2
46.93	46.96		5		"	"	23.7
45.85	45.87		ln		"	"	36.3
	43.88				"	9.8	59.0
42.08	42.11		3		0.83	"	79.6
41.47	41.48		1		"	"	86.8
41.12			1		"	"	90.8
40.34	40.37		2		"	"	99.7
39.46	39.57		2		"	"	34009.4
	38.46				"	"	21.6
	37.99				"	"	27.1
37.01	37.04		2		"	"	38.1
	36.30				"	"	46.7
35.7			ln		"	"	54.
35.22	35.24		5		"	"	59.1
34.45			1		"	"	68.2
34.30	34.33		1		"	"	69.7
34.07	34.01		3		"	"	73.0
33.73	33.71		1		"	"	76.6
32.81	32.79		2		"	"	87.3
30.96			3		"	"	34108.7
29.92			1		"	"	20.8
29.55	29.57		2		"	"	25.0
28.42	28.38		3		"	"	38.5
28.28			3		"	"	40.0
27.19	27.19		5		"	"	51.7
26.25	26.26		3		"	"	63.6
23.80	23.72		4		"	"	92.7
23.57	23.58		3		"	"	95.0
21.92	21.88		4		"	"	34214.5
21.32	21.35		5		"	9.9	21.0
18.4			ln		"	"	55.
17.2	17.38		ln		"	"	68.5
16.17	16.12		1		"	"	81.9
15.58	15.56		3		"	"	88.7
15.34	15.34		3		"	"	91.4
13.83			1		"	"	34309.2
13.60			1		"	"	11.9
11.78	11.79		4		"	"	33.3
11.25	11.27		1		"	"	39.5
10.98	11.13		1		"	"	41.9
10.73	10.73		3		"	"	45.7
09.13	09.12		1		"	"	64.7
08.38	08.40		1		"	"	73.4
	07.15		1		"	"	88.0
06.25	06.32		1		"	"	98.2

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney			Lohse	$\lambda +$	
2905.55	2905.60		ln	0.83	9.9	34406.7
	04.78			"	"	16.1
04.16	04.08		2	"	"	23.9
03.67	03.79		2	0.82	"	28.6
02.98	02.92		1	"	"	37.8
02.76	02.73		1	"	"	40.2
01.13	01.10		1	"	"	59.6
2899.58	2899.61		3	"	"	77.1
99.26	99.26		3	"	"	81.7
98.60	98.64		7	"	"	89.3
97.79	97.83		4	"	"	98.9
97.35	97.33		1	"	"	34504.5
96.85	96.85		2	"	10.0	10.2
96.56	96.52		4	"	"	13.9
95.78	95.82		2	"	"	22.8
95.13	95.02		1	"	"	31.4
94.90	94.95		2	"	"	33.2
94.5			ln	"	"	38.
94.33	94.38		3	"	"	40.0
93.57			1	"	"	49.4
93.36	93.34		1	"	"	52.0
93.07	93.04		2	"	"	55.6
92.84			1	"	"	58.1
91.99	91.98		2	"	"	68.3
91.55			2	"	"	73.5
	91.38			"	"	75.6
91.28			3	"	"	76.8
91.13			3	"	"	78.6
89.96	89.95		4	"	"	92.6
89.59	89.60		4	"	"	96.9
89.26	89.31		4	"	"	34600.9
88.81	88.85		4	"	"	06.1
87.87	87.88		3	"	"	17.5
87.08	87.13		1	"	"	26.8
86.50	86.50		1	"	"	34.0
85.38	85.39		1	"	"	47.4
81.99	82.05		5	"	"	87.9
80.95	81.00		6	"	"	34700.5
79.33	79.34		1	"	"	20.2
79.25			1	"	"	21.3
78.52	78.53		3	"	"	30.0
78.03	78.13		4	"	"	35.4
76.75			1	"	"	51.4
76.37	76.37		5	"	"	56.0
76.07	76.06		6	"	"	59.7
75.13			3	"	"	71.0
74.51	74.63		1	"	"	77.8
73.91	73.90		4	"	"	85.9
73.57	73.57		5	"	"	89.9
71.70			1	"	10.1	34812.5
71.55	71.58		2	"	"	14.1
70.51	70.54		8	"	"	26.7
68.8			ln	"	"	48.
67.70	67.73		7	"	"	60.9
67.21	67.20		3	"	"	67.1

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
2866·80	2866·83		7		0·82	10·1	34871·8
66·01	65·98		2		"	"	81·8
65·76			1		"	"	84·7
65·47			3		"	"	88·2
65·22	65·24		6		"	"	91·1
62·62	62·68		9		0·81	"	34922·6
61·01	61·05		7		"	"	45·0
60·0			ln		"	"	55·
59·00	59·01		6		"	"	67·1
58·72	58·76		3		"	"	70·4
58·06	58·09		3		"	"	78·5
57·49	57·50		5		"	"	85·6
56·85	56·89		5		"	"	93·2
56·43	56·48		2		"	"	98·2
55·73	55·79		7		"	"	35006·8
55·13	55·17		4		"	"	14·3
54·72	54·74		1		"	"	19·5
54·25	54·25		2		"	"	25·4
53·88	53·83		1		"	"	30·2
53·30	53·30		5		"	"	37·0
52·76	52·80		2		"	"	43·4
52·35	52·39		3		"	"	48·5
51·41	51·41		8		"	"	60·3
50·78	50·76		1		"	"	68·2
50·38			1		"	"	73·0
49·98	49·93		5		"	"	78·5
49·84			5		"	"	79·6
49·41	49·40		2		"	"	85·1
48·47	48·52		3		"	"	96·2
46·80	46·82		1		"	10·2	35116·8
46·51	46·52		3		"	"	20·5
46·4			2a		"	"	22·
44·96			ln		"	"	39·7
43·35	43·39		10c		"	"	59·3
	43·19				"	"	61·7
	43·09				"	"	62·8
42·87			1		"	"	65·5
42·49			ln		"	"	71·2
40·57			1		"	"	94·0
40·10	40·13		7		"	"	99·6
39·33			1		"	"	35209·4
38·87	38·67		5		"	"	16·3
	38·92 ?				"	"	
37·96	38·06		2		"	"	25·8
36·55	36·65		3		"	"	43·3
35·75	35·75		10r		"	"	53·8
34·83	34·93		6		"	"	64·7
33·48	33·51		1		"	"	81·9
32·54	32·53		6		"	"	93·9
31·63			ln		"	"	35305·1
31·17			ln		"	"	10·9
30·69			3		"	"	16·9
30·57	30·46		6		"	"	19·1
	29·68				"	"	29·5
28·88	28·76		1		"	"	0·2

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda}$	
2828.01	2828.01		1		0.81	10.2	35350.4
26.50			1		"	"	69.2
26.23			2		"	"	72.2
26.15	26.09		ln		"	"	74.0
25.80			1		"	"	78.0
25.57	25.37		2		"	"	82.1
24.64			1		0.80	"	92.5
22.47	22.40		8		"	10.3	35420.1
22.10	21.93		6		"	"	25.4
	20.52				"	"	44.2
18.42	18.39		7		"	"	70.8
18.01	17.95		2		"	"	76.1
17.65			ln		"	"	80.3
17.1			2b		"	"	87.
16.89	16.88		4		"	"	89.9
14.57			1		"	"	35519.1
14.29			1		"	"	22.6
13.59			1		"	"	31.4
12.03	12.07		9		"	"	50.9
11.55	11.56		1		"	"	57.2
11.15			2		"	"	62.3
11.0	10.93		2b		"	"	64.7
10.3	10.19		2b		"	"	73.8
09.71			1		"	"	80.6
09.35			1		"	"	85.1
08.08	08.07		2		"	"	35601.3
07.74			1		"	"	05.5
04.1	04.09		1b		"	"	51.2
03.42			2		"	"	60.4
03.31			1		"	"	61.7
02.7			1b		"	"	70.
00.81	00.81		9		"	"	93.6
00.23	00.22		4		"	"	35701.1
2798.82	2798.75		2		"	10.4	19.5
98.69			2		"	"	20.6
95.90			1		"	"	56.3
95.62			1		"	"	59.8
94.55			ln		"	"	73.5
93.72	93.75		2		"	"	84.0
92.20	92.20		9		"	"	35803.6
91.79			1		"	"	08.9
91.54			1		"	"	12.1
91.00			1		"	"	19.0
89.43	89.43		6		"	"	39.2
89.15			1		"	"	42.8
87.97	87.92		2		"	"	58.7
87.67	87.67		6		"	"	61.8
86.54	86.55		5		"	"	76.3
85.73	85.75		8		"	"	86.7
85.18	85.31		1		"	"	93.1
84.40	84.55		1		"	"	35903.0
	83.95				0.79	"	09.8
83.41]			2		"	"	16.7
82.70	82.64		3		"	"	26.3
82.42	82.43		4		"	"	20.5

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo	
Exner and Haschek	Adeney			Lohse	$\lambda +$		$\frac{1}{\lambda} -$
2781.17	2781.04		2		0.79	10.4	35946.5
80.97			3		"	"	48.3
80.35	80.35		7		"	"	56.3
79.00	78.98		1		"	"	73.9
78.57			1		"	"	79.3
78.11	78.15		8		"	"	85.0
	77.37				"	"	94.9
76.81	76.71		2		"	"	36002.8
76.1			1b		"	"	11.
74.50	74.51		6		"	10.5	32.0
73.39	73.40		4		"	"	46.4
72.45	72.36		1		"	"	59.3
72.0	72.08		2b		"	"	64.0
71.35	71.40		1		"	"	72.7
70.0	69.93		1b		"	"	91.1
69.4	69.52		1b		"	"	97.6
68.65	68.60		6		"	"	36108.5
68.21	68.28		1		"	"	13.5
67.70	67.70		1		"	"	20.6
67.32			1		"	"	25.5
66.61	66.63		10		"	"	34.7
65.96	65.97		3		"	"	43.2
65.70	65.72		2		"	"	46.6
65.52	65.46		3		"	"	49.4
65.19			1		"	"	53.4
65.05	65.05		1		"	"	55.2
64.37	64.38		2		"	"	64.1
64.05	64.03		2		"	"	68.4
63.57	63.66		3		"	"	74.0
62.85			3n		"	"	84.0
62.70	62.76		10		"	"	85.6
61.80	61.77		1n		"	"	98.0
61.21			1		"	"	36205.5
60.92			1		"	"	09.3
60.60	60.57		2		"	"	13.7
60.45			2		"	"	15.5
60.24	60.17		2				18.2
60.09							
59.78	59.80		3		"	"	20.2
59.46	59.41		4		"	"	24.1
59.02	59.01		4		"	"	28.5
58.67			2		"	"	34.3
57.75	57.77		8		"	"	38.8
57.00	56.98		3		"	"	50.8
56.35	56.33		5		"	"	60.9
	55.84				"	"	69.5
55.56	55.55		3		"	"	76.1
54.35	54.33		5		"	"	79.8
53.99	53.93		3		"	"	95.8
53.72	53.73		3		"	"	99.6
53.37			1		"	"	36304.0
52.90	52.88		1		"	"	08.5
52.46			1		"	"	15.0
51.91	51.92		8		"	"	20.6
50.78	50.77		8		"	10.6	27.8
					"		42.8

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
2749.88	2749.84		3		0.79	10.6	36354.9
49.01	49.04		8		"	"	65.9
48.36			1		"	"	74.7
48.00			1		"	"	79.5
47.88	47.84		1		"	"	81.3
46.23	46.22		0		"	"	36403.0
45.50	45.28		1		"	"	12.6
45.03	44.98		5		"	"	19.2
44.65	44.62		3		"	"	24.1
43.67	43.67		8		"	"	36.9
43.25			2		"	"	42.5
42.12	42.12		8		"	"	57.5
41.16	41.13		2		0.78	"	70.5
40.13	40.12		5		"	"	84.1
39.83			1		"	"	88.0
39.60			4		"	"	91.1
39.5			2n		"	"	92.
37.70	37.70		1		"	"	36516.4
37.55			1		"	"	18.4
37.17	37.14		1		"	"	23.7
37.10			1		"	"	24.4
36.80			1		"	"	28.4
36.50	36.50		1		"	"	32.4
35.84	35.80		2		"	"	41.5
34.64	34.62		2		"	"	56.0
34.13			1		"	"	64.1
33.63			1		"	"	70.8
32.52			1		"	"	85.6
31.97	31.93		2		"	"	93.3
31.6			ln		"	"	98.
30.80			1		"	"	36608.7
30.4			ln		"	"	14.
29.82			1		"	"	21.8
28.25	28.24		2		"	"	43.0
27.81	27.33		6		"	"	48.8
26.57	26.58		2		"	10.7	65.3
26.34			2		"	"	68.5
25.0			1		"	"	86.
24.11	24.12		6		"	"	98.5
23.77	23.68		5		"	"	36703.7
23.6			3n		"	"	05.
22.82	22.80		8		"	"	16.1
20.93			ln		"	"	41.4
20.79	20.74		2		"	"	43.7
20.36			3		"	"	49.1
20.13	20.18		4		"	"	51.9
19.8			ln		"	"	57.
19.40			1		"	"	62.1
19.12			1		"	"	65.9
18.45	18.45		8		"	"	75.0
18.15			2		"	"	79.0
17.58	17.60		6		"	"	86.6
17.13			1		"	"	92.8
17.00			1		"	"	94.6
16.27			1		"	"	3804.5

CHROMIUM (SPARK SPECTRUM)—*continued.*

Exner and Haschek	Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Lohst			$\lambda +$	$\frac{1}{\lambda} -$	
2715.75			1n		0.78	10.7	36811.5
15.15			1n		"	"	19.7
12.96	2712.77		2		"	"	50.7
12.39	12.40		7		"	"	56.5
11.96			1		"	"	63.0
11.3			1n		"	"	72.
11.00	11.04		7		"	"	89.4
09.49	09.40		7		"	"	97.2
08.88	08.88		7		"	"	36904.9
06.63			1		"	"	35.6
06.25			1n		"	"	40.8
	06.02				"	"	44.0
05.55	05.62		1		"	"	50.2
04.9	04.90		1b		"	"	59.2
03.97	03.90		3n		"	"	72.4
03.65	03.65		6		"	"	76.3
03.03			1		"	10.8	84.7
02.66			1		"	"	89.8
02.10	02.08		1		"	"	97.6
01.77	01.77		2n		"	"	37002.0
01.35			2n		"	"	07.7
01.20			3		"	"	09.8
00.68			1		"	"	16.9
00.1	00.20		1n		"	"	24.2
2699.75			1		"	"	29.7
99.20			1		"	"	37.2
98.89	2698.86		4		0.77	"	41.7
98.72			4		"	"	43.8
98.49	98.53		5		"	"	46.7
98.2			2b		"	"	51.
98.00	98.02		6		"	"	53.6
97.59	97.64		5		"	"	59.8
96.86	96.87		3		"	"	70.7
96.22			1		"	"	78.2
94.83	94.83		1		"	"	97.3
93.9			1b		"	"	37110.
93.62			7		"	"	14.0
93.14			1		"	"	20.6
92.21	92.28		3		"	"	32.9
91.15	91.20		9		"	"	47.7
90.48	90.42		1n		"	"	59.2
89.89	89.98		1		"	"	64.8
89.33	89.35		5		"	"	73.1
89.20			2n		"	"	75.0
88.43	88.50		4		"	"	85.1
88.34			6		"	"	86.9
87.19			9		"	"	37202.8
86.50	86.25		1		"	"	14.1
86.06	86.17		1		"	"	17.7
85.24			2		"	"	29.8
85.12	84.88		2		"	"	33.1
84.23	84.41		1		"	"	42.6
83.87			1		"	"	48.8
83.56	83.58		3		"	"	53.0
81.60	81.98		1		"	"	77.7

.CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuum
Exner and Haschek	Adeney			Lohse	$\lambda +$	
2680.98	2681.03	1		0.77	10.8	37288.6
80.43	80.46	2		"	"	96.4
80.32		1		"	"	98.2
80.00	80.00	2		"	"	37302.6
78.88	78.88	9		"	10.9	18.9
77.31		7		"	"	40.0
77.20	77.20	7		"	"	41.6
76.62		1		"	"	49.7
75.78	75.76	4		"	"	61.5
75.36	75.33	1		"	"	67.5
	74.75			"	"	75.8
74.3	74.17	1b		"	"	83.0
73.60		1		"	"	91.8
72.91	72.91	8		"	"	37401.5
72.48	72.43	3		"	"	07.9
71.90	71.88	9		"	"	15.8
71.0		ln		"	"	28.
70.30		4		"	"	38.1
70.17	70.18	5		"	"	39.8
68.78	68.77	8		"	"	59.5
68.05	68.00	2b		"	"	70.0
67.35		ln		"	"	79.7
66.12	66.15	8		"	"	96.6
65.7	65.68	3b		"	"	37502.8
63.78	63.66	6		"	"	30.6
63.45	63.46	7		"	"	34.3
63.10	63.14	2		"	"	39.0
62.78		1		"	"	43.8
62.22		1		"	"	51.7
61.85	61.81	4		"	"	57.3
61.75		3		"	"	58.4
61.4	61.44	5b		"	"	63.0
60.85	60.83	ln		"	"	71.3
59.83		1		"	"	85.5
59.57		1		"	"	90.0
59.01	59.01	3		"	"	97.0
58.65	58.70	8		"	"	37601.8
57.65	57.78	2b		"	"	15.4
57.20	57.34	ln		"	"	21.7
55.85	56.00	1		"	"	40.8
55.37		ln		"	"	48.9
54.2		1b		0.76	11.0	65.
53.63	53.62	8		"	"	73.3
52.90		1		"	"	83.6
52.2	52.24	2b		"	"	93.3
51.55		ln		"	"	37702.8
50.88		1		"	"	12.3
49.73		1		"	"	28.7
48.4	48.31	1b		"	"	48.3
48.16		2		"	"	51.1
47.5		1b		"	"	60.
44.3		1b		"	"	37806.
43.62	43.62	2		"	"	15.9
43.08	43.00	1		"	"	24.2
42.20		1		"	"	36.2

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	
Exner and Haschek	Adeney		Lohse	$\lambda + \frac{1}{\lambda} -$		
2641·91			2	0·76	11·0	37840·4
‡ 41·47	2641·50		1	"	"	46·5
40·81			1	"	"	56·2
40·1			1n	"	"	66·
39·2			1b	"	"	79·
38·6			1n	"	"	88·
38·12			1	"	"	94·8
37·56	37·58		2	"	"	37903·0
37·26	37·28		1	"	"	07·0
36·90			1	"	"	12·3
36·78			1	"	"	14·0
36·54	36·55		1	"	"	17·3
35·9	35·93		1b	"	"	26·5
34·4	34·38		1b	"	"	48·4
33·8	33·63		1b	"	"	58·1
32·7	32·67		1b	"	"	73·0
31·00	31·03		3	"	11·1	97·0
29·65	29·66		1	"	"	38016·7
29·12			1	"	"	24·4
‡ 28·06	28·13		2	"	"	39·3
26·87	26·88		2	"	"	57·0
26·16			1	"	"	67·3
25·75			1	"	"	73·3
24·0			1b	"	"	99·
23·48	23·42		3b	"	"	38106·6
20·60	20·60		2n	"	"	48·1
19·7	19·79		3b	"	"	60·6
18·8	18·75		2b	"	"	74·7
‡ 16·60	16·42		2	"	"	38206·4
‡ 16·28						
14·7	14·80		2b	"	"	33·5
13·62	13·62		1	"	"	50·0
13·3	13·17		1b	"	"	55·7
12·63	12·65		1	"	"	64·4
12·5	12·19		1n	"	"	68·7
11·70	11·70		1	"	"	78·1
11·0	11·04		3b	"	"	88·1
10·2	10·20		2b	"	"	38300·1
09·4			1b	0·75	11·2	12·
08·94	08·90		1	"	"	18·8
08·28			1	"	"	28·2
08·01	08·01		4	"	"	32·2
07·73			1	"	"	36·3
	07·11			"	"	45·4
06·65	06·61		3	"	"	52·5
06·20	06·22		2	"	"	58·7
05·76	05·72		2	"	"	65·6
04·26	04·26		2	"	"	87·4
03·85	03·81		1	"	"	93·8
03·1	03·15		1b	"	"	38404·2
02·00	01·92		1	"	"	21·4
01·70						
01·17						
00·3			1b	"	"	33·0
2597·00	2597·22		1	"	"	46·
				"	"	93·1

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
†2596.22			4n		0.75	11.2	38506.3
95.68	2595.70		3n		"	"	14.2
94.4	94.42		1b		"	"	33.2
93.58			1		"	"	45.5
91.98	92.00		1		"	"	69.2
90.88	90.90		5		"	"	85.6
90.6			2b		"	"	90.
89.83	89.83		3		"	"	38601.4
89.16	89.20		2		"	"	11.3
88.36	88.36		1		"	11.3	21.2
88.3			1n		"	"	24.
87.53	87.56		3		"	"	35.3
86.78			1		"	"	46.8
85.70	85.79		1		"	"	62.3
85.0	85.13		1b		"	"	72.5
84.66			1		"	"	78.5
84.22	84.26		4		"	"	84.8
83.75	83.78		1		"	"	91.9
82.9			1b		"	"	38705.
82.71	82.79		1		"	"	07.1
82.40	82.33		2		"	"	12.4
82.22					"	"	15.1
80.87			1		"	"	35.3
80.6			1b		"	"	39.
79.9			1b		"	"	50.
79.24	79.28		2		"	"	59.5
78.87			1n		"	"	65.4
78.39	78.45		4		"	"	72.1
77.80	77.85		1		"	"	81.1
76.22			1		"	"	38805.3
75.91	75.90		2		"	"	10.0
74.30			1		"	"	34.2
73.66	73.66		4		"	"	43.9
72.6			1b		"	"	60.
72.24	72.28		1		"	"	65.0
71.90	71.91		4		"	"	70.4
	70.86				"	"	86.2
69.55	69.60		1n		"	"	38905.6
68.67	68.69		2n		"	11.4	19.1
67.70	67.68		1		"	"	34.1
67.45			1		"	"	37.7
66.98			1		"	"	44.9
66.63	66.63		1		"	"	50.2
66.4			1n		"	"	54.
64.87	64.91		2		0.74	"	76.6
64.5			1		"	"	83.
63.71	63.71		5		"	"	94.6
63.45	63.49		3		"	"	98.2
62.63	62.56		2		"	"	39010.8
61.9	61.80		2b		"	"	22.9
61.13	61.08		2		"	"	34.2
60.82	60.80		1		"	"	38.7
59.92	59.93		2n		"	"	52.1
58.90			1n		"	"	67.8
58.45	58.45		1n		"	"	74.7

CHROMIUM (SPARK SPECTRUM)—*continued.*

Exner and Haschek	Wave-length		Intensity and Character	Previous Observa- tions (Hassel- berg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
2557.98			1		0.74	11.4	39081.8
57.56			1		"	"	88.3
57.22	2557.16		1		"	"	93.5
57.10			1		"	"	95.3
55.65	55.59		2n		"	"	39117.9
52.03			1		"	"	73.0
51.71	51.70		4		"	"	78.0
50.96			1		"	"	89.4
50.40			1		"	"	98.0
50.10			1		"	"	39202.6
49.65	49.60		1		"	"	10.0
48.71	48.70		3		"	11.5	24.1
48.16	48.16		2		"	"	32.5
47.7	47.57		2b		"	"	40.6
46.56	46.55		1		"	"	57.2
46.1	46.12		1b		"	"	64.1
45.30			2		"	"	76.6
44.46	44.45		2		"	"	89.6
43.24	43.25		3		"	"	39308.3
42.88			1n		"	"	13.9
40.60			1n		"	"	49.3
38.5	38.49		5b		"	"	81.9
37.84			2		"	"	92.1
34.43	34.42		4		"	"	39445.2
32.8			1b		"	"	70.
31.96	31.92		2		"	"	83.9
31.13	31.18		2		"	"	96.4
30.32	30.30		4		"	11.6	39509.2
30.06	30.05		5		"	"	13.2
27.53			1		"	"	52.7
27.22	27.20		1		"	"	57.7
	25.52				"	"	84.2
24.75			1b		"	"	96.3
23.8			3b		"	"	39611.
23.38	23.58		4		"	"	18.2
22.75	22.39		1		"	"	27.7
20.73	20.75		3		"	"	65.3
19.63	19.65		2n		"	"	76.6
19.0	19.00		2n		"	"	86.7
18.40	18.35		4n		"	"	96.5
17.5			1b		0.73	"	39710.
16.70	16.71		3n		"	"	22.9
16.01			1		"	"	33.9
15.70			4n		"	"	38.8
13.80	13.72		4n		"	"	69.4
12.95			1b		"	"	72.3
12.50			1		"	"	89.4
12.12			1n		"	"	95.4
11.30	11.28		1		"	11.7	39809.5
10.33	10.35		2		"	"	23.5
09.15	09.15		1b		"	"	42.4
08.17			1		"	"	58.0
07.62			1		"	"	66.7
06.93			1		"	"	77.7
06.50			2		"	"	84.6

CHROMIUM (SPARK SPECTRUM)—*continued.*

Exner and Haschek	Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
2505.95			1		0.73	11.7	39893.3
05.15			1n		"	"	39906.1
04.38	2504.38		1		"	"	18.3
02.4	02.61		1b		"	"	48.3
01.56	01.55		1		"	"	63.8
2499.5			1b		"	"	96.0
	2498.82				"	"	40007.2
	98.06				"	"	19.4
96.9	96.95		3b		"	"	37.1
96.4	96.45		2b		"	"	45.6
92.98	92.95		3		"	11.8	40101.1
92.72	92.70		3		"	"	05.2
	91.57				"	"	23.5
	90.85				"	"	35.1
89.85			2n		"	"	51.3
89.35	89.32		3		"	"	59.6
87.13			1n		"	"	95.2
86.73	86.73		2		"	"	40201.6
86.36	86.39		2		"	"	07.4
85.54			2n		"	"	50.9
83.85	83.85		4r		"	"	48.3
83.12	83.11		4r		"	"	60.2
	80.80				"	"	97.8
79.89			4		"	"	40312.6
78.63	78.81		2		"	"	31.6
77.78	77.71		1n		"	"	47.5
76.95	77.01		2		"	"	59.0
75.74	75.76		2		"	11.9	79.9
75.0	75.05		2b		"	"	91.7
72.93	72.87		3		"	"	40426.4
70.83			1n		"	"	60.3
70.05			1		"	"	73.1
69.51			2		0.72	"	82.0
69.20	69.22		2		"	"	86.9
	68.07				"	"	40505.5
66.6	66.62		2b		"	"	29.6
66.28			1		"	"	35.0
65.83			2		"	"	42.4
65.66	65.69		2		"	"	44.9
65.01			2		"	"	55.9
64.6	64.52		1b		"	"	63.3
63.56	63.56		1		"	"	79.7
62.44			2		"	"	98.2
60.49	60.56		2		"	"	40629.8
59.5			1n		"	12.0	47.
56.90	56.75		2n		"	"	90.9
55.8			1b		"	"	40708.
	55.30				"	"	16.2
54.55	54.51		3		"	"	29.0
54.13	54.11		2		"	"	35.8
52.78	52.90		2		"	"	57.1
51.73			1n		"	"	75.5
50.44			2		"	"	97.0
50.04			2		"	"	40803.7
49.70	49.70		3		"	"	09.3

CHROMIUM (SPARK SPECTRUM)—*continued.*

Exner and Haschek	Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
2446.98	2447.70		2		0.72	12.0	40842.7
45.15	47.07		1n		"	"	54.4
43.43			1		"	"	85.3
38.50	38.50		4		"	12.1	40914.0
35.36			1		"	"	96.7
33.24	33.23		3		"	"	41049.6
29.82			1		"	"	85.4
25.30			1		"	"	41143.2
20.20	20.13		2		"	12.2	41219.9
19.94			1		0.71	"	41307.3
19.44			1		"	"	11.1
16.46	16.45		3		"	"	19.7
15.3			1b		"	"	70.7
13.73			1		"	"	90.
08.87	08.81		2n		"	"	41417.4
05.37			1n		"	12.3	41501.4
04.15			1		"	"	61.3
03.98			1		"	"	82.4
03.65			1		"	"	85.4
00.35	00.35		2		"	"	91.1
2399.74	2399.73		2		"	"	41648.3
98.58			1		"	"	59.0
97.83	97.76		3		"	"	79.0
95.49			1n		"	12.4	92.7
94.57			4		"	"	41732.8
	94.01				"	"	48.7
93.47			1		"	"	58.5
92.95			1		"	"	67.9
92.15			1		"	"	77.0
91.52			1		"	"	91.0
89.81	89.78		3		"	"	41802.0
81.55	81.50		4		"	"	32.2
81.16			1		"	12.5	41977.4
71.28			1		"	"	83.8
66.90	66.96		3		0.70	"	42158.8
65.32	65.35		2		"	12.6	42236.7
64.10			1		"	"	64.7
† 60.9			1n		"	"	86.8
55.38			1		"	"	42344.
52.75			1n		"	"	42443.4
52.10			1n		"	12.7	90.7
45.38	45.43		3		"	"	42502.5
44.66	44.60		2		"	"	42623.9
42.57			1		"	"	38.0
40.60			1		"	"	75.5
37.83			2		"	12.8	42711.3
35.45			1		"	"	61.9
34.91			1		"	"	42805.5
34.72			1		"	"	15.4
34.51	34.41		1		"	"	18.9
34.32			1		"	"	23.7
33.97			1		"	"	26.2
33.58	33.55		2		"	"	32.7
33.20			1		"	"	40.1
			1		"	"	46.8

CHROMIUM (SPARK SPECTRUM)—*continued.*

Exner and Haschek	Wave-length		Intensity and Character	Previous Observations (Hasselberg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
2330.15			1		0.70	12.8	42902.9
29.42			1		"	"	16.3
27.83			1		"	"	45.7
	2326.50				"	12.9	70.1
25.00	24.97		5		0.69	"	98.1
20.52			1		"	"	43080.9
20.21	20.09		3		"	"	87.8
	19.90				"	"	91.4
19.50	19.50		4		"	"	99.8
19.16	19.07		4		"	"	43107.0
18.95			ln		"	"	10.0
14.80	14.78		5		"	"	87.6
13.95			ln		"	13.0	43203.1
10.18			2		"	"	73.7
07.7			1b		"	"	43320.
07.33	07.30		3		"	"	27.4
06.97			1		"	"	33.9
04.17			1		"	"	86.6
03.00			1		"	"	43408.6
00.68	00.68		2		"	13.1	52.3
00.26			1		"	"	60.3
2299.7			ln		"	"	71.
98.06			1		"	"	43501.9
97.34	2297.34		2		"	"	15.5
97.03			2		"	"	21.4
95.70			2		"	"	46.6
94.58			1		"	"	67.9
92.7			ln		"	"	43604.
92.0			ln		"	"	17.
91.26			1		"	"	31.0
90.82	90.78		2		"	"	39.8
89.40	89.40		2		"	"	66.5
87.33			1		"	13.2	43705.9
86.74			1		"	"	17.2
86.40			1		"	"	23.7
84.61			2		"	"	58.0
84.25			1		"	"	64.8
82.53			1		"	"	97.8
77.60	77.68		2		0.68	"	43891.9
76.56			2		"	"	43912.7
75.61	75.66		2		"	13.3	30.5
73.50	73.50		2		"	"	71.7
71.15			ln		"	"	44017.3
68.49			1		"	"	68.9
65.06			2		"	"	44135.6
62.79			1		"	13.4	79.8
61.82			2		"	"	98.8
60.3			ln		"	"	44228.
58.73			2		"	"	59.3
58.15	58.01		2n		"	"	72.0
57.92			ln		"	"	75.1
57.72			ln		"	"	79.1
57.57			ln		"	"	82.0
56.76			1		"	"	97.9
56.50			1		"	"	44303.0

CHROMIUM (SPARK SPECTRUM)—*continued.*

Exner and Haschek	Wave-length		Intensity and Character	Previous Observa- tions (Hassel- berg ²)	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda}$	
2256.15			2		0.68	13.4	44309.9
55.61			1		"	"	20.5
52.11			1		"	"	89.4
51.60			2		"	"	99.5
51.28			1		"	"	44405.8
50.09			1		"	13.5	29.2
49.89			2		"	"	33.1
49.05			1		"	"	49.7
48.68	2248.65		2		"	"	57.1
48.40			2		"	"	62.6
48.01			1		"	"	70.3
47.79			1		"	"	74.6
45.48			1		"	"	44520.4
45.02			1		"	"	29.5
44.23	44.23		2		"	"	45.2
43.73	43.75		2		"	"	54.9
43.39			2		"	"	61.9
41.94			2		"	"	90.7
41.45			1		"	"	44600.5
39.6			1		"	"	37.
39.3			1		"	"	43.
37.71			2		"	13.6	74.9
36.03	36.00		2		"	"	44708.8
34.67			1		"	"	35.7
33.92			2		"	"	50.8
31.94			2		"	"	90.5
31.59			1		"	"	97.5
31.15			1		"	"	44806.3
28.87			1		0.67	"	52.2
28.4			1		"	"	62.
28.02			1		"	"	69.5
26.80	26.89		2		"	13.7	93.0
26.42			1		"	"	44901.8
24.9			1b		"	"	32.
22.00			1		"	"	90.8
19.73			1		"	"	45036.8
18.83			1		"	"	55.1
17.89			1n		"	"	74.2
17.62			2		"	"	79.7
15.9			1		"	"	45115.
15.20			1		"	13.8	28.8
13.81			2		"	"	57.2
12.38			1		"	"	86.4
11.94			1		"	"	95.4
11.4			1n		"	"	45206.
08.84			1		"	"	58.8
04.69			1n		"	"	45344.1
04.0			1n		"	"	58.
03.34			2		"	13.9	71.8
02.09			1		"	"	97.5
01.3			1n		"	"	45414.
00.6			1n		"	"	28.
2198.77			1		"	"	66.1
98.02			1		"	"	81.6
96.98			1		"	"	93.1

CHROMIUM (SPARK SPECTRUM)—*continued.*

Wave-length			Intensity and Character	Previous Observa- tions (Hassel- berg*)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek	Adeney	Lohse			$\lambda +$	$\frac{1}{\lambda} -$	
2193·47			l		0·67	13·9	45576·0
91·75			l		"	14·0	45611·6
91·41			l		"	"	18·7
90·94			l		"	"	30·6
90·26			l		"	"	42·7
85·17			l		"	"	45749·0
83·86			l		"	"	76·5
82·85			ln		"	"	97·7
71·25			l		0·66	14·1	46042·3
70·81			l		"	"	51·7
66·4			ln		"	14·2	46145·
52·9			ln		"	14·3	46435·
50·8			ln		"	"	80·
49·7			lb		"	"	46504·
48·8			lb		"	"	23·
47·7			lb		"	14·4	47·
47·3			l		"	"	56·
44·3			2		"	"	46621·
41·3			2n		"	"	86·
40·6			ln		"	"	46701·
39·3			l		"	"	30·
35·5			l		"	14·5	46813·
34·7			2		"	"	30·
34·3			l		"	"	39·
33·6			l		"	"	55·
33·1			l		"	"	66·
32·7			l		0·65	"	74·
30·4			l		"	"	46925·
30·0			l		"	"	34·
21·4			l		"	14·6	47124·
17·6			l		"	"	47209·
15·0			l		"	14·7	67·
13·8			l		"	"	93·

PALLADIUM.

Kayser, 'Astrophys. Jour.,' vii. p. 99, 1898.

Rowland and Tatnall, 'Astrophys. Jour.,' iii. p. 291, 1896.

Exner and Haschek, 'Sitzber. kaiserl. Akad. Wissensch. Wien,' civ. (2), p. 950, 1895; cv. (2), p. 533, 1896; cvi. (2), p. 45, 1897.

Adeney, 'Roy. Dublin Soc. Trans.,' vii. p. 331, 1901.

Lohse, 'Publ. Potsdam Obs.,' xii. (3), No. 41, 1902.

Exner and Haschek, 'Wellen-längen-Tabellen . . . der ultravioletten Bogen-spektren der Elemente,' Leipzig 1904, p. 116.

The lines marked A are distinctly recorded in Adeney's photograph of the spark spectrum.

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda}$	
5760.122		1			1.57	4.7	17356.0
39.881		4			1.56	"	17417.3
37.842		3			"	"	23.4
36.826		5			"	"	26.5
00.978		0			1.55	4.8	17536.0
5695.293		9			"	"	53.6
90.333		4			"	"	68.9
87.670		2			"	"	77.1
80.993		0			"	"	97.8
74.432		2			"	"	17618.1
70.263		10			"	"	31.1
68.605		2			"	"	36.2
64.578		1			1.54	"	48.8
55.628		5n			"	"	76.7
42.898		5			"	"	17716.6
21.520		2			1.53	"	84.0
19.667		9			"	"	89.8
08.229		5n			"	4.9	17826.0
01.867		3			"	"	46.3
5562.902		2n			1.52	"	17971.3
48.514		2n			1.51	"	18017.9
47.219		9			"	"	22.1
42.997		10			"	"	35.9
29.657		6			"	"	79.4
5497.056		4			1.50	5.0	18186.6
35.379		3			1.48	"	18393.0
27.425		1			"	"	18419.9
5395.471		8b ^v			1.47	5.1	18529.0
94.958		4b ^r			"	"	30.7
85.668		0			"	"	62.7
77.833		1n			"	"	89.7
63.474		1			1.46	"	18639.5
62.864		4b ^v			"	"	41.7
46.980		0			"	"	97.0
45.278		4			"	"	18703.0
12.752		4			1.45	"	18817.5
5295.744		10			"	5.2	77.9
94.267		2			"	"	83.1
56.321		3			1.44	"	19019.5
34.992		7			1.43	"	97.0
09.044		4			1.42	"	19102.2
5163.970		10			1.41	5.3	19359.6
61.491		1			"	"	69.0

PALLADIUM—continued.

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda} -$	
5127·849		2			1·40	5·3	19496·1
17·158		7			"	5·4	19536·7
14·530		2			"	"	46·7
10·940		6			"	"	60·4
01·704		1			"	"	95·9
5063·549		4			1·38	"	19743·6
4972·081		3			1·36	5·5	20107·1
30·145		1			1·35	5·6	20277·8
24·373		0			"	"	20301·5
19·008		3			"	"	23·7
4875·577		7			1·34	"	20504·8
36·654		0			1·32	5·7	20669·7
22·347		0			"	"	20731·1
17·662		9			"	"	51·2
17·26		0n			"	"	53·0
4791·061		0			1·31	"	20866·5
88·327		8	4788·0	ln	"	"	78·4
76·715		1			"	5·8	20929·2
			68·4	ln	"	"	66·0
62·098		0			1·30	"	93·3
			55·5	1	"	"	21022·0
			43·1	2	"	"	77·0
			33·5	1	"	"	21120·0
24·204		3			1·29	"	61·8
			14·4	1	"	"	21206·0
08·261		0			"	"	33·5
† 4677·617		4			1·28	5·9	21372·0
			4671·1	2	"	"	21402·0
			36·9	ln	"	"	21560·0
32·770		2			1·27	6·0	79·4
			04·4	ln	"	"	21712·0
			03·7	ln	"	"	16·0
			4598·5	ln	"	"	40·0
			96·6	ln	"	"	49·0
			93·3	ln	"	"	65·0
			91·5	ln	"	"	73·0
† 4590·191		3n			1·26	"	79·6
† 53·096		2	53·0	ln	1·25	6·1	21957·0
† 41·314		5n	41·4	1	1·24	"	22016·0
			31·1	ln	"	"	64·0
			19·1	ln	"	"	22122·0
† 16·406		5n	16·4	ln	"	"	35·4
† 4497·813		2	4497·6	ln	1·23	"	22226·9
† 89·641		4n	89·5	ln	"	6·2	67·4
Δ† 73·771	4473·761	7s	73·77	6	"	"	22346·3
69·307		0			"	"	68·6
58·785		2			1·22	"	22421·4
43·191		3	43·1	ln	"	"	22500·1
			33·1	lb	"	"	51·0
† 21·217		ln	21·0	ln	"	6·3	22611·9
			09·0	ln	1·21	"	74·0

† Observed also *in the arc* by Exner and Haschek whose numbers are 4677·63 (1n), 4590·2 (1n), 4553·1 (1n), 4541·30 (2n), 4516·41 (2n), 4497·8 (1n), 4489·65 (2n), 4473·76 (10), 4421·2 (1n).

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda}$	
† 4406·759		5	4406·6 4396·1	1n	1·21	6·3	22686·1 22741·0
† 4388·770		2	88·6	1	1·20	„	79·1
† 86·614		1	86·5	1	„	„	90·8
79·8		0n			„	„	22826·
60·4		0n	77·7	1n	„	„	37·
58·773		0n			„	6·4	22927·
† 51·1		2n			„	„	35·8
† 44·8		4n	44·9	1n	1·19	„	76·
28·125		0n			„	„	23010·
21·8		0n			„	„	98·3
			15·0	1n	1·18	„	23132·
			4283·3	1b	„	6·5	69·
			81·8	1n	1·17	„	23340·
			75·1	1b	„	„	48·
† 4268·4		4n	68·5	1n	„	„	85·
			64·0	1n	„	„	23421·
			26·9	1	1·16	„	46·
			24·8	1	„	6·6	23651·
			15·9	1	„	„	63·
			14·6	2	„	„	23713·
A† 13·116	4213·115	6r	13·12		„	„	20·
			4199·4	1	1·15	6·7	28·8
			83·4	1	„	„	23806·
A† 4170·005	4170·006	5	70·02	4	„	„	97·
			66·4	1	1·14	„	23974·1
			64·9	1	„	„	95·
			63·1	1n	„	„	24003·
			A 57·1	1	„	„	14·
			41·0	1n	„	6·8	48·
			40·3		„	„	24142·
			28·0	1b	1·13	„	46·
			24·3	1n	„	„	24218·
† 23·761		2	23·6	1n	„	„	39·
			18·9	1n	„	„	42·9
			13·7	1n	„	„	71·
			03·2	1n	„	„	24302·
					„	„	64·
† 4101 } † to 4098 }		b			„	„	
			4090·3	1	1·12	6·9	24441·
			88·8	1	„	„	50·
A† 4087·518	4087·513	6s	87·48	8	„	„	57·8
			84·6	1n	„	„	75·
			66·6	1n	„	„	24584·
			63·6	2	„	„	24602·
			57·88	4	„	„	37·1
			51·5	1	1·11	7·0	75·
			39·5	1	„	„	24748·
† 21·2		0n	21·0	1b	„	„	24861·

† Observed also *in the arc* by Exner and Haschek whose numbers are 4406·79 (2n), 4388·80 (1), 4386·65 (1n), 4351·15 (1b), 4344·75 (2b), 4268·4 (1b), 4213·11 (20), 4170·02 (5), 4123·79 (2), 4099 (2b), 4087·52 (10), 4021 (1b).

PALLADIUM—continued.

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kaysr	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda} -$	
† 4020·3		ln	4020·0	1b(Ir)	1·11	7·0	24867·
			14·0	1b	1·10	"	24906·
11·8		On			"	"	19·
† 07·6		On	07·5	1b	"	"	46·
† 3992·5		ln			"	7·1	25040·
			3982·3	l	"	"	25104·
			79·0	ln	"	"	25·
			74·0	ln	1·09	"	56·
			73·5	2	"	"	60·
			71·5	ln	"	"	72·
			A 69·3	l	"	"	86·
			66·4	l	"	"	25250·
*† 38·777	3958·772	5r	58·80	10	"	"	53·3
			44·2	l	"	7·2	25346·
			40·3	1b	"	"	72·
			28·1	l	1·08	"	25450·
			27·1	l	"	"	57·
			25·7	ln	"	"	66·
			24·5	ln	"	"	74·
			23·1	ln	"	"	83·
			14·3	l	"	"	25540·
			13·8	l	"	"	43·
			13·6	l	"	"	44·
			13·2	l	"	"	47·
			12·8	l	"	"	50·
			11·8	l	"	"	56·
			11·2	l	"	"	60·
			10·6	l	"	"	64·
			10·0	l	"	"	68·
			09·3	l	"	"	72·
			08·6	l	"	7·3	77·
			06·8	l	"	"	89·
			06·5	l	"	"	91·
			06·1	l	"	"	94·
			05·7	l	"	"	96·
			05·2	l	"	"	25600·
			04·3	ln	"	"	05·
			02·3	ln	"	"	19·
			00·8	ln	"	"	29·
			3896·1	l	1·07	"	59·
A*† 3891·335	3891·334	6r	94·37	8	"	"	71·0
			90·6	ln	"	"	96·
			87·5	l	"	"	25716·
			87·1	l	"	"	19·
			84·3	ln	"	"	37·
			83·3	ln	"	"	48·
			82·6	ln	"	"	49·
			81·0	l	"	"	59·
			75·6	1b	"	"	95·

Channelled band.

† Observed also *in the arc* by Exner and Haschek, whose numbers are 4020 2 (1b), 4007·6 (1b), 3992·4 (1b), 3958·79 (20), 3894·33 (20).

* Observed also by Lohse, who also gives lines at 3968·62 (1·0), 3961·65 (0·1n), 3958·79 (7·0), 3894·37 (7·5), 3933·78 (2·0), 3919·25 (0·6n), 3902·27 (0·1), 3882·98 (0·2n), 3882·28 (0·2n), 3864·68 (0·1n), 3843·26 (0·1n).

PALLADIUM—*continued*.

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda} -$	
			3873·7	In	1·07	7·3	25808·
			72·0	l	"	"	19·
			71·5	l	"	"	22·
			70·0	l	"	"	32·
			69·7	In	"	"	34·
			67·9	In	"	"	46·
			67·3	In	"	"	50·
			63·7	In	"	"	75·
			62·0	lb	"	"	86·
			52·7	In	1·06	"	25948·
			51·0	lb	"	"	60·
			48·3	In	"	"	78·
			47·6	In	"	"	83·
			43·3	In	"	"	26012·
			34·4	2	"	"	72·
			A*†32·41	8	"	"	86·0
			31·3	l	"	"	93·
			28·05	6	"	"	26115·0
			23·6	l	"	"	46·
			23·2	l	"	"	49·
			22·1	l	"	"	56·
			21·9	l	"	"	58·
			21·7	l	"	"	60·
			18·7	lb	"	"	80·
			17·7	In	"	7·4	86·
			16·3	l	1·05	"	96·
			14·9	l	"	"	26206·
			13·1	l	"	"	18·
			10·1	l	"	"	39·
			09·9	l	"	"	40·
		‡	07·9	In	"	"	54·
			05·4	l	"	"	71·
			02·8	l	"	"	89·
			01·2	l	"	"	26300·
A†3799·332	3799·335	5r	3799·34	l	"	"	12·5
			98·7	l	"	"	17·
			98·2	l	"	"	21·
			97·4	In	"	"	26·
			95·1	2	"	"	42·
			91·8	l	"	"	65·
			88·7	In	"	"	87·
			87·9	l	"	"	92·
			85·3	In	"	"	26411·
			83·6	In	"	"	23·
			81·8	lb	"	"	35·
			79·0	2	"	"	55·
			78·6	l	"	"	57·
			76·7	l	1·04	"	71·

* Lohse, 3842·61 (0·In), 3839·36 (0·3b), 3832·44 (3·0), 3827·16 (0·In), 3825·41 (0·In), 3818·89 (0·In), 3808·09 (0·In), 3802·69 (0·2), 3778·98 (0·In), 3753·07 (0·In), 3738·96 (1·0), 3719·10 (2·5), 3697·27 (0·1).

† Observed also *in the arc* by Exner and Haschek, whose numbers are 3832·45 (10), 3799·31 (10).

‡ Double.

PALLADIUM--*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				$\lambda +$	$\lambda -$	
			3772.2	ln	1.04	7.5	26502.
			71.2	1b	"	"	09.
			65.7	1	"	"	48.
			61.6	1	"	"	77.
			59.5	1	"	"	92.
			55.0	1	"	"	26624.
			53.6	ln	"	"	34.
			52.5	ln	"	"	41.
			51.7	ln	"	"	47.
			51.0	ln	"	"	52.
			46.0	1	"	"	88.
			45.7	2	"	"	90.
			40.5	ln	"	"	26727.
			A 38.98	6	"	"	37.8
			32.4	ln	1.03	"	85.
			27.7	2	"	"	26819.
			25.2	1	"	7.6	37.
			22.7	2	"	"	55.
A† 3719.061	3719.046	4r	* 19.06	10	"	"	80.9
			12.7	ln	"	"	26927.
			11.4	1	"	"	36.
			10.9	1	"	"	40.
			00.7	1	"	"	27014.
A† 3690.491	3690.483	6r	* 3692.4	2	1.02	"	75.
			90.44	10	"	"	89.1
			88.6	1	"	"	27103.
			88.1	1	"	"	67.
			87.5	1	"	"	11.
			83.60	4	"	7.7	39.7
			82.7	ln	"	"	46.
			80.0	1	"	"	66.
			78.9	1	"	"	74.
			77.0	1b	"	"	88.
			74.0	1	"	"	27211.
			72.0	1	"	"	25.
			71.4	1	"	"	30.
			70.2	2	"	"	39.
			65.0	1b	"	"	77.
	62.520	2n			"	"	95.9
† 54.574		2	54.3	1	1.01	"	27355.3
			51.5	1	"	"	78.
			50.3	ln	"	"	87.
			49.8	ln	"	"	91.
			47.9	2	"	"	27412.
† 46.116		1	46.0	1	"	"	18.7
			44.8	1	"	"	29.
			43.2	1	"	"	41.
			42.9	1	"	"	43.
A*† 34.340	34.841	10r	34.83	10b	"	7.8	27503.8
			31.5	2	"	"	29.
			23.8	ln	"	"	87.

* Lohse, 3690.50 (5.5), 3634.85 (10.0), 3616.31 (0.1n).

† Observed also *in the arc* by Exner and Haschek, whose numbers are 3719.06 (15), 3690.49 (20r), 3654.57 (1), 3646.14 (1), 3634.85 (200r).

1906.

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Reduction to Vacuum		Oscillation Frequency in Vacuo	
Kayser	Rowland and Tatnall			Intensity and Character	$\lambda +$		$\lambda -$
A*† 3609·698	3609·696	9r	3623·2	ln	1·01	7·8	27592·
			22·0	ln	"	"	27601·
			21·5	1	"	"	05·
			18·9	2	"	"	25·
			13·7	ln	1·00	"	65·
			09·67	10b	"	"	95·3
			06·8	1	"	"	27718·
			05·5	1	"	"	28·
			01·7	1	"	"	57·
			3598·7	1	"	"	80·
*† 3596·795	3596·804	2	97·0	1	"	"	93·
			96·6	2b	"	"	94·7
			95·7	1	"	"	27803·
			89·0	1b	"	7·9	55·
			84·5	ln	"	"	90·
			84·1	ln	"	"	93·
			80·9	ln	"	"	27918·
			77·9	ln	0·99	"	41·
			77·5	1	"	"	45·
			75·0	1	"	"	64·
A*† 71·305 † 66·775	71·302 66·781	5r 2	72·6	1	"	"	83·
			71·31	10	"	"	93·1
			66·9	2	"	"	28028·6
			66·6	2	"	"	30·
			65·3	2	"	"	40·
			61·7	1	"	"	69·
			61·2	1	"	"	72·
			60·3	1	"	"	80·
			58·4	1	"	"	95·
			54·9	1	"	"	28122·
A*† 53·242	53·236	7r	53·23	10	"	"	35·4
			46·4	1	"	8·0	90·
			42·2	ln	"	"	28223·
			* 39·2	ln	"	"	47·
			36·7	ln	0·98	"	67·
			36·4	ln	"	"	69·
			35·8	ln	"	"	74·
			35·5	ln	"	"	76·
			34·2	ln	"	"	87·
			33·0	10b	"	"	97·
*† 28·881	28·878	2	28·7	2	"	"	28329·6
			27·3	1	"	"	42·
			26·7	1	"	"	47·
			25·3	1	"	"	58·
			23·8	1	"	"	70·
			A 21·40	4	"	"	89·8
A*† 17·087	17·096	Sr	17·10	10	"	"	28418·3
			13·9	1	"	"	50·
			A* 08·09	4	"	8·1	98·1

* Lohse, 3609·69 (10·0), 3596·77 (0·2n), 3596·20 (0·1n), 3571·31 (2·8), 3553·27 (7·5), 3539·65 (0·1), 3528·87 (0·1n), 3517·13 (6·0), 3508·09 (0·2).

† Observed also *in the arc* by Exner and Haschek, whose numbers are 3609·71 (100r), 3596·81 (2), 3571·29 (20r), 3566·77 (3), 3553·24 (50r), 3528·86 (2), 3517·08 (100r), 3507·48 (1).

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda}$	
			3505.5	ln	0.98	8.1	28518.
			04.7	ln	"	"	25.
			03.7	l	"	"	33.
			01.7	l	"	"	49.
			3499.5	ln	"	"	67.
			97.7	l	0.97	"	82.
			95.6	ln	"	"	99.
			93.1	ln	"	"	28619.
*† 3489.930	3489.915	4r	89.91	6	"	"	45.8
† 88.293		0			"	"	59.2
	86.112	1			"	"	77.4
A*† 81.308	81.300	7r	81.3	10	"	"	28716.7
			77.6	ln	"	"	47.
			75.8	l	"	"	62.
			75.5	l	"	"	65.
			74.7	l	"	"	71.
			72.9	ln	"	"	86.
			71.3	ln	"	"	00.
			71.0	ln	"	8.2	28802.
			69.5	ln	"	"	14.
			A 68.72	4	"	"	20.9
A*† 60.888	60.884	7r	60.92	10	"	"	86.1
			57.7	ln	0.96	"	28913.
			A* 51.42	8	"	"	65.6
			49.6	l	"	"	81.
† 42.545	42.548	2			"	"	29040.1
A*† 41.548	41.539	6r	41.56	10	"	"	48.4
A*† 33.582	33.578	5r	33.57	10	"	"	29115.9
			33.0		"	8.3	21.
A*† 21.368	21.367	8r	21.53	10	"	"	29219.8
† 19.818	19.805	4	19.7	l	"	"	33.0
			18.1	ln	"	"	48.
			15.0	l	0.95	"	74.
			11.6	l	"	"	29303.
			11.2	l	"	"	07.
			08.01	l	"	"	34.4
			07.3	l	"	"	40.
† 06.210	06.196	1			"	"	49.8
A*† 04.732	04.725	10r	04.71	10	"	"	62.6
			3397.6	ln	"	"	29424.
† 3396.926		3	97.0	2(Rh)	"	"	30.1
96.081		0			"	8.4	37.3
			95.3	l	"	"	44.
			94.6	l	"	"	50.
			93.0	ln	"	"	64.
			91.6	ln	"	"	76.
† 89.192	3389.195	2	89.3	ln	"	"	97.2
88.811		0			"	"	29500.5
			88.0	ln	"	"	08.

* Lohse, 3489.95 (2.6), 3481.35 (4.0), 3464.15 (0.1), 3460.94 (3.0), 3451.49 (1.2), 3441.62 (2.8), 3433.62 (1.8), 3421.40 (2.7n), 3404.77 (3.0n).

† Observed also in the arc by Exner and Haschek, whose numbers are 3489.93 (15), 3488.31 (1), 3481.31 (50r), 3460.93 (50r), 3442.54 (2), 3442.13 (1), 3441.54 (20r), 3433.59 (20r), 3421.42 (50r), 3419.83 (3), 3406.20 (1), 3404.73 (100r), 3396.94 (3), 3389.20 (1).

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda} -$	
A 3383·025		4	3386·5	ln	0·95	8·4	29520·
			85·7	ln	"	"	28·
			83·9	l	"	"	43·
			83·0	2	"	"	50·9
			82·6	ln	"	"	55·
† 80·840	3380·832	5n	81·0	2	"	"	70·0
A*† 73·137	73·139	6r	80·5	ln	"	"	73·
			77·0	ln	0·94	"	29604·
			76·3	ln	"	"	10·
			73·16	10	"	"	37·6
			71·5	l	"	"	52·
			66·1	l	"	"	29700·
			65·8	l	"	"	02·2
			63·9	l	"	"	19·
			62·2	lb	"	"	34·
			61·4	l	"	"	41·
			60·3	lb	"	8·5	51·
			59·0	lb	"	"	68·
			55·9	ln	"	"	90·
			53·6	ln	"	"	29810·
			52·3	ln	"	"	22·
			51·2	ln	"	"	32·
			49·6	2	"	"	46·
			49·2	ln	"	"	50·
			46·9	2	"	"	70·
			46·268		0	46·4	ln	"	"	75·5
44·5	lb	"				"	91·
41·9	lb	"				"	29915·
40·7	lb	"				"	25·
38·0	lb	0·93				"	50·
36·2	lb	"				"	66·
30·8	l	"				"	30014·
27·40	4	"				"	36·0
25·1	lb	"				8·6	66·
23·1	l	"				"	84·
† 21·100			21·1	l	"	"	30101·9
			18·6	lb	"	"	25·
17·455					"	"	35·0
			17·2	lb	"	"	37·
† 13·093			16·0	lb	"	"	48·
			11·7	ln	"	"	74·7
† 11·136					"	"	87·
					"	"	92·5
10·251			10·2	ln	"	"	30200·8
			06·9	ln	"	"	31·
A† 02·253	02·256	30r	02·25	10	"	"	73·7
00·325				"	"	91·4	
†3299·875				0·92	"	95·6	
			3296·0	lb	"	"	30331·2

* Lohse, 3373·15 (0·2).

† Observed *in the arc* by Exner and Haschek, whose numbers are 3380·89 (8), 3373·21 (30r), 3321·15 (2), 3313·10 (2), 3311·15 (2), 3302·28 (30r), 3300·00 (1).

PALLADIUM—continued.

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda} -$	
			3294.0	ln	0.92	8.6	30350.
			92.8	ln	"	"	61.
			90.5	lb	"	"	82.
A† 3287.378	3287.377		87.35	4	"	8.7	30410.7
† 86.337					"	"	20.3
			86.0	lb	"	"	33.
			84.6	l	"	"	36.
84.080					"	"	41.2
			79.1	ln	"	"	87.
			78.5	ln	"	"	93.
			77.2	ln	"	"	30505.
			76.7	ln	"	"	10.
			75.3	ln	"	"	23.
			74.1	2	"	"	34.
A 72.925			72.7	2	"	"	45.0
			69.7	ln	"	"	75.
			67.4	6	"	"	97.
			62.5	2	"	"	30643.
A† 58.907	58.900	25r	58.92		0.91	"	76.4
A† 51.754	51.760	20r	51.80	8	"	8.8	30743.8
			49.7	l	"	"	63.
			43.2	2	"	"	30825.
A 42.824	42.828	60r	42.85	10	"	"	28.5
			38.7	l	"	"	68.
			36.7	l	"	"	87.
			36.2	l	"	"	92.
			34.7	l	"	"	30906.
			32.5	l	"	"	27.
			31.0	l	"	"	41.
			29.3	ln	"	"	58.
			28.0	l	"	"	70.
			26.5	lb	"	"	84.
			23.7	lb	"	"	31011.
			22.2	lb	"	"	26.
			21.0	lb	0.90	"	37.
† 19.088	19.097		19.1	l	"	"	55.9
			16.5	lb	"	"	81.
			14.2	ln	"	8.9	31103.
			13.5	l	"	"	09.8
13.018		0					14.5
			A 10.60	4	"	"	37.9
			09.9	4	"	"	45.
			09.5	l	"	"	49.
			05.4	"	"	"	88.
			† 04.1	l	"	"	31201.
			03.7	lb	"	"	05.
			02.7	lb	"	"	15.
			00.8	l	"	"	33.
			3195.5	lb	"	"	85.
			91.0	lb	"	"	31329.

† Observed in the arc by Exner and Haschek, whose numbers are 3287.38 (10), 3286.38 (ln), 3259.01 (30), 3251.89 (30), 3248.13 (1), 3242.83 (100r), 3219.08 (3), 3204.14 (1).

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuum
Kayser	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda} -$	
			3185.0	1b	0.90	8.9	31388.
			A 79.5	1	0.89	9.0	31442.
			78.9	2	"	"	48.
			75.1	2	"	"	86.
			73.9	1	"	"	98.
			72.0	1b	"	"	31517.
			A 70.40	4	"	"	32.8
		In	68.0	1n	"	"	56.4
			64.2	1	"	"	95.
			63.0	2	"	"	31606.
			A 62.08	4	"	"	15.7
			57.0	1	"	"	67.
			56.5	1	"	"	72.
			A 55.75	4	"	"	79.2
			54.3	1	"	"	94.
			53.4	1b	"	"	31703.
			50.2	1n	"	"	35.
		0	48.8	1n	"	"	52.8
			47.9	1n	"	"	58.
			45.0	1n	"	"	87.
A†	42.932	3142.927	A 42.93	4	"	9.1	31808.3
	39.804				0.88	"	29.9
†	39.531				"	"	42.8
	38.417				"	"	54.1
			37.7	1b	"	"	61.
			36.8	1n	"	"	70.
			A 32.4		"	"	31915.
			31.5	1b	"	"	24.5
			29.8	1b	"	"	42.
			28.2	1n	"	"	58.
			27.0	1n	"	"	70.
			25.8	1b	"	"	83.
			22.7	1n	"	9.2	32014.
A†	14.157	14.152	14.15	8	"	"	32102.2
			13.9		"	"	05.
			11.5	1	"	"	30.
A†	09.276		09.1		"	"	52.6
	07.435				"	"	71.7
			A 05.4		"	"	93.
	03.909				"	"	32208.4
	03.176				"	"	15.8
			3095.2	1b	0.87	"	99.0
			92.7	1	"	"	32325.
	3089.756				"	"	55.8
	88.636				"	"	66.5
			88.0	1	"	"	74.
			86.5	1n	"	"	90.
			82.2	1b	"	9.3	32435.
			78.6	1n	"	"	73.
	78.356				"	"	75.6
			77.2	1n	"	"	88.

† Observed also *in the arc* by Exner and Haschek, whose numbers are 3142.97 (10), 3139.54 (1), 3114.19 (30), 3109.25 (2).

PALLADIUM—continued.

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				λ_+	λ_-	
† 3075.274		4	3075.1	1	0.87	9.3	32508.1
73.924		0			"	"	22.4
			69.2	1	"	"	72.
			69.0	1	"	"	75.
68.564		0			"	"	79.2
			67.8	1	"	"	87.
67.243		0	67.3	1	"	"	93.2
† 66.210		1	66.0	ln	"	"	32604.2
† 65.425	3065.408	6r	A 65.2	4	"	"	12.8
			64.6	2	"	"	22.
		1			"	"	32.7
63.537		0			0.86	"	44.5
62.430		0n			"	"	46.
62.3			60.4	1	"	"	66.
			A 59.55	4	"	"	75.8
			57.3	1	"	"	99.
			54.2	ln	"	9.4	32732.
			A 52.25	4	"	"	53.3
			A 50.0	2	"	"	78.
49.502		0			"	"	82.8
			47.7	1	"	"	32802.
			47.1 †	ln	"	"	09.
			46.5	1	"	"	15.
† 46.614		2			"	"	13.9
			46.0	1	"	"	20.
			42.6	1	"	"	57.
			41.6	2	"	"	68.
41.102		0			"	"	73.4
39.648		0			"	"	89.2
38.830		0			"	"	98.0
			38.3	ln	"	"	32904.
			37.4	1	"	"	13.
36.220		1			"	"	26.3
			34.1	2	"	"	49.
† 32.324		1	A 32.30	6	"	"	68.6
			30.0	1	"	"	94.
29.600		0			"	"	98.3
† 28.894		1			"	"	33006.0
A† 28.031	28.031	6r	28.08	6	"	"	15.4
			26.4	1b	"	"	33.
			25.9	1	"	"	39.
25.094		0			"	9.5	47.3
22.744		0	22.7	1	0.85	"	73.0
† 21.859		3			"	"	82.8
† 20.835		2	{ 21.0 } { 20.6 }	1	"	"	93.9
			19.7	1	"	"	33106.
			A 19.0	ln	"	"	14.
15.052		0	15.0	ln	"	"	57.4
14.733		1			"	"	60.9

† Observed also in the arc by Exner and Haschek, whose numbers are 3075.28 (3), 3066.20 (2), 3065.41 (20), 3046.61 (1), 3032.30 (1), 3028.86 (2), 3028.05 (20), 3021.87 (3), 3020.79 (3).
‡ Double.

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Rowland and Tatnall				$\lambda +$	$\frac{1}{\lambda} -$	
			3014.0	1b	0.85	9.5	33169.
†	3010.980	1			"	"	33203.1
			09.6	2	"	"	17.
	09.093	3	09.1	1	"	"	23.1
			08.0	1	"	"	35.
†			07.0	1	"	"	46.
			05.3	1n	"	"	65.
			04.9 ‡	1n	"	"	69.
A †	02.775	5r	02.81	4	"	"	93.0
			01.6	1n	"	"	33306.
			01.2	1	"	"	10.
			2997.9	1	"	"	47.
	2996.660	0			"	9.6	60.9
	95.400	0			"	"	74.9
			94.4	2	"	"	86.
			93.7	1	"	"	94.
			89.7	1n	"	"	33439.
			85.5	1	"	"	86.
			83.6 ‡	1n	"	"	33507.
†			A 80.78	8	0.84	"	38.7
			77.7	1b	"	"	73.
	75.953	0			"	"	93.1
			73.2	1	"	"	33624.
			70.6	1n	"	9.7	53.
			70.3	1n	"	"	56.
	68.356	0			"	"	79.0
			67.0	1	"	"	94.
			66.3	1n	"	"	33702.
			65.3	1n	"	"	14.
			64.3	1n	"	"	25.
			62.9	1n	"	"	41.
	62.443	0			"	"	46.2
			60.7	1n	"	"	66.
			60.0	1n	"	"	74.
			59.7	1n	"	"	77.
			58.6	1n	"	"	89.
			57.5	1n	"	"	33803.
A	56.811	0	56.7	2	"	"	10.5
			55.7	1b	"	"	23.
			A 54.0	1	"	"	43.
			53.5	1n	"	"	48.
			52.5	1n	"	"	60.
			52.0	1n	"	"	66.
	51.134	0			"	"	75.6
	50.920	1			"	"	78.0
			50.3	1	"	"	85.
			49.6	1	"	"	93.
			47.8	1b	"	"	33914.
			46.7	1b	"	"	27.
			45.2	1	"	9.8	44.
			44.6	1	"	"	51.

† Observed also *in the arc* by Exner and Haschek, whose numbers are 3009.88 (3), 3007.37 (1), 3002.74 (10), 2980.78 (1n).

‡ Double.

PALLADIUM—continued.

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda} -$	
			2943.5	ln	0.84	9.8	33963.
2938.552		0			0.83	"	34020.6
36.901		2	37.0	l	"	"	39.7
36.570		0			"	"	43.5
			A 35.2	2n	"	"	59.
32.4		6r			"	"	92.
†			31.5	l	"	"	34102.
			31.2	l	"	"	06.
			27.5	2	"	"	49.
			A 25.6	2n	"	"	71.
† 22.615		7r	22.7	4	"	"	34206.1
			22.3	l	"	"	10.
			20.8	lb	"	9.9	27.
			19.5	ln	"	"	41.
			18.4	l	"	"	55.
			A 17.5	l	"	"	66.
			A 15.3	ln	"	"	92.
			A 12.3	ln	"	"	34327.
			11.3	lb	"	"	39.
			07.5	lb	"	"	84.
			06.0	l	"	"	34402.
			03.4	l	0.82	"	31.
			02.0	lb	"	"	49.
			2900.5	lb	0.82	9.9	67.
			2898.0	l	"	"	97.
			97.2	ln	"	"	34506.
			95.0	ln	"	10.0	32.
			94.0	l	"	"	44.
			A 93.2	2	"	"	54.
			90.3	l	"	"	88.
			90.1	l	"	"	91.
			89.7	l	"	"	96.
			89.1	l	"	"	34603.
			86.8	l	"	"	30.
			83.8	ln	"	"	66.
			81.6	l	"	"	93.
			80.7	ln	"	"	34705.
			A 78.20	4n	"	"	34.0
2875.875	2875.85	1			"	"	62.0
			73.5	l	"	"	91.
			A 71.45	4n	"	10.1	34815.5
			70.5	ln	"	"	27.
			63.5	2	0.81	"	34912.
			62.7	ln	"	"	22.
			61.8	l	"	"	33.
			59.4	l	"	"	62.
A 54.694	54.68	2	54.73	8	"	"	35019.9
			53.83	ln	"	"	51.0
			52.2	4	"	"	51.
			50.8	ln	"	"	68.
49.912	49.90	2	49.9	l	"	"	78.7

† Observed also in the arc by Exner and Haschek, whose numbers are 2931.59 (2), 2922.63 (10).
‡ Double.

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda} -$	
2846.4		2n	2848.8	1	0.81	10.1	35092.
			46.8	ln	"	10.2	35121.9
			43.0	ln	"	"	64.
			A 41.18	4	"	"	86.4
			A 40.08	4	"	"	35200.1
39.5	2839.5	10b	A 37.8 †	ln	"	"	07.0
37.2		2n	35.9	l	"	"	28.
					"	"	36.0
35.385		0			"	"	52.
35.133		0			"	"	58.4
					"	"	61.5
			31.7	l	"	"	35304.
			29.6	l	"	"	30.
			29.4	l	"	"	33.
			26.74	ln	"	"	67.0
			25.8	ln	"	"	78.
	24.51	1			"	"	94.2
			23.2	ln	0.80	10.3	35410.
			21.9	ln	"	"	27.
			18.0	l	"	"	76.
			A 14.2	2	"	"	35523.
			11.7	l	"	"	55.
			10.2	ln	"	"	74.
			A 08.6	ln	"	"	95.
07.8	07.8	ln	07.7	2n	"	"	35604.8
06.561	06.55	1	06.5	ln	"	"	20.5
			05.4	ln	"	"	35.
			04.6	ln	"	"	45.
			03.8	ln	"	"	56.
			02.6	l	"	"	71.
A 02.009		3	02.1	l	"	"	78.4
			01.6	l	"	"	84.
			01.1	ln	"	"	90.
			2799.5	ln	"	10.4	35710.
			98.7	l	"	"	20.
			98.4	l	"	"	24.
			96.7	l	"	"	46.
			95.6	l	"	"	60.
			95.2	l	"	"	65.
			94.8	l	"	"	70.
			94.3	l	"	"	77.
			91.7	ln	"	"	35810.
			A 88.10	4n	"	"	56.3
			81.7	l	0.79	"	35939.
			79.8	l	"	"	63.
			A 77.0	4	"	"	36000.
			75.0	l	"	"	25.
A 2763.199	2763.19	10r	63.13	4	"	10.5	36179.7
			62.1	l	"	"	94.
			60.7	ln	"	"	36212.
			55.1	l	"	"	86.
			54.0	l	"	"	36300.
51.972		2			"	"	27.1
			51.3	ln	"	10.6	36.

† Double.

PALLADIUM—continued.

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	
Kayser	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda} -$		
2734·095	2742·48	2	A	2750·8	ln	0·79	10·6	36342·
				50·3	ln	"	"	49·
				49·40	4	"	"	61·0
				44·7	ln	"	"	36423·
				42·7	2	"	"	50·0
				40·8	1	0·78	"	75·
				40·4	1	"	"	80·
				39·6	2	"	"	91·
				38·8	1	"	"	36502·
				37·0	1	"	"	26·
				36·3	1	"	"	35·
				35·7	ln	"	"	43·
				34·1	1	"	"	64·6
				31·9	2	"	"	94·
				30·8	1	"	"	36609·
				30·2	1	"	"	17·
				30·0	1	"	"	19·
				29·5	1	"	"	26·
				28·0	2	"	"	46·
	27·2	ln	"	10·7	57·			
	26·3	ln	"	"	69·			
	24·2	1	"	"	97·			
	19·1	1	"	"	36766·			
	17·7	ln	"	"	85·			
	16·9	1	"	"	96·			
	A 14·98	4	"	"	36822·0			
	A 14·38	4	"	"	30·1			
	13·2	ln	"	"	46·			
	12·5	1	"	"	56·			
	11·9	1	"	"	64·			
	10·5	1	"	"	83·			
	09·2	ln	"	"	36901·			
	08·7	ln	"	"	07·			
	07·3	1	"	"	26·			
	07·1	1	"	"	29·			
	06·5	1	"	"	37·			
	06·0	1	"	"	44·			
	04·1	1	"	"	70·			
	03·5	1	"	"	78·			
	02·5	2	"	10·8	92·			
	01·7	1	"	"	37003·			
	00·8	ln	"	"	16·			
	00·6	ln	"	"	18·			
	A2698·8	2	0·77	"	43·			
	96·5	1	"	"	74·			
	94·9	1	"	"	96·			
	94·0	1	"	"	37109·			
92·7	1	"	"	27·				
92·4	1	"	"	30·				
91·5	1	"	"	43·				
A 88·6	2	"	"	83·				
A 87·8	2	"	"	94·				
2686·373	2686·38	2					37214·1	
				85·5	1	"	"	26·
				84·0	1	"	"	47·

§ Occurs also in Pt and Ir.

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo			
Kayser	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda} -$				
A 2658·819	2679·18	1	2683·4	1	0·77	10·8	37255·			
			81·0	1b	"	"	89·			
			A 79·7	1	"	"	37307·0			
			79·2	1n	"	"	13·			
			77·9	1	"	10·9	31·			
	76·06	2Au?		77·2	1	"	"	42·		
				76·0	1	"	"	58·0		
				61·2	2	"	"	66·		
				59·4	1	"	"	92·		
				58·82	6	"	"	99·8		
55·1	55·2	2b	57·6	2	"	"	37617·			
			55·7	1n	"	"	41·			
					"	11·0	52·			
			54·0	1	0·76	"	68·			
			53·7	2n	1	"	72·			
			41·149		0	51·0	1	"	"	37710·
						47·8	1	"	"	56·
						47·6	1	"	"	59·
						46·9	1	"	"	69·
						45·8	1	"	"	85·
42·3	1	"				"	37835·			
41·3	1n	"				"	49·			
40·7	1n	"				"	51·3			
40·3	1	"				"	58·			
38·4	1	"				"	63·			
31·692	36·01	2	37·7	1	"	"	91·			
			37·2	2	"	"	37901·			
			A 36·5	1n	"	"	08·			
			36·03	8	"	"	18·			
			34·7	1n	"	"	24·8			
			33·3	1	"	"	44·			
					"	"	64·			
					"	11·1	87·3			
			31·3	1	"	"	93·			
			31·1	1	"	"	96·			
14·270	1		30·3 [‡]	1	"	"	38007·			
			29·7	1n	"	"	16·			
			28·9	1n	"	"	28·			
			A 28·38	6	"	"	35·1			
			26·3	1n	"	"	65·			
			24·6	1	"	"	90·			
			21·6	1n	"	"	38133·			
			21·2	1n	"	"	39·			
			20·4	1n	"	"	51·			
			18·8	1n	"	"	74·			
14·270	1		18·0	1	"	"	86·			
			17·5	1	"	"	93·			
			17·0	1	"	"	38201·			
			15·2	1n	"	"	27·			
					"	"	40·5			
			13·4	2	"	"	53·			
			13·0	1n	"	"	59·			
			11·7	2	"	"	78·			

‡ Double.

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kaysor	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda} -$	
2609·716		0	2609·7	2	0·75	11·1	38307·2
			09·4		"	11·2	12·
			07·0	2	"	"	47·
			06·3	1	"	"	57·
			06·2	1	"	"	59·
			05·5	1	"	"	69·
05·157	2605·19	3			"	"	74·2
			Δ 03·7	1	"	"	96·
			03·5	1	"	"	99·
	02·87	1	{ 03·3	1	"	"	38402·
			{ 02·6	2	"	"	12·
			01·8	ln	"	"	24·
			00·9	ln	"	"	37·
	2596·09	1	Δ 2596·02	4	"	"	38509·3
			Δ 94·3	ln	"	"	35·
			93·7	1	"	"	44·
	93·36	1	93·30	4	"	"	49·8
			93·0	1	"	"	54·
			91·6	1	"	"	75·
			91·0	ln	"	"	84·
			90·2	1	"	"	96·
			88·7	ln	"	"	38618·
			87·5	1	"	11·3	36·
	83·95	1	Δ 83·95	4	"	"	89·1
			82·6	2	"	"	38708·
			82·0	1	"	"	18·
			79·1	ln	"	"	62·
			78·5	1	"	"	71·
			77·9	1	"	"	80·
	77·20	1	Δ 77·13	4	"	"	89·6
			Δ 76·4	2	"	"	38802·
			Δ 75·5	2	"	"	16·
			74·3	1	"	"	34·
			72·8	ln	"	"	57·
			71·3	1	"	"	79·
			Δ 70·8	1	"	"	87·
Δ 2565·595	69·65	2	69·58	4	"	"	38905·6
	65·60	3	65·55	8	"	11·4	65·9
			64·6	1	0·74	"	81·
64·0	64·2	1b			"	"	90·0
			63·5	1	"	"	98·
			63·3	1	"	"	39001·
			62·6	1	"	"	11·
	61·14	1	61·0	1	"	"	36·0
			57·3	1	"	"	92·
			54·1	1	"	"	39141·
			52·5	1	"	"	66·
51·971	51·95	2	51·98	8	"	"	74·0
51·095	51·10	1			"	"	87·4
	50·76	1	{ 51·0	6	"	"	89·
			{ 50·6	2	"	"	95·
			49·3	1	"	"	39215·
			49·1	1	"	"	20·
			48·7	1	"	11·5	24·
48·165		0			"	"	31·4

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda}$	
2546-990		0	2547.1	l	0.74	11.5	39249.
			46.6	l	"	"	49.5
46.283		0		l	"	"	56.
44.821		4	44.8	l	"	"	61.4
			43.5	l	"	"	84.3
			43.1	l	"	"	39300.
			42.0	l	"	"	04.
39.690		0	39.4	2	"	"	28.
			38.8	l	"	"	63.4
			38.0	l	"	"	77.
			37.0	l	"	"	90.
6.872		2	36.8	l	"	"	39405.
	2534.70	2	34.70	4	"	"	06.8
			33.6	l	"	"	40.9
			32.7	ln	"	"	58.
			32.3	ln	"	"	72.
			30.5	l	"	"	78.
			29.6	l	"	"	39506.
			27.4	l	"	11.6	20.
			27.0	l	"	"	55.
			26.3	l	"	"	61.
			25.4	ln	"	"	72.
			24.2	ln	"	"	86.
			22.9	ln	"	"	39605.
			22.6	ln	"	"	25.
			21.9	ln	"	"	30.
			21.5	ln	"	"	41.
21.102		0		ln	"	"	47.
			19.0	ln	"	"	53.6
			18.2	l	"	"	87.
			16.1	l	0.73	"	99.
			15.4	l	"	"	39732.
			14.52	4	"	"	43.
13.0	13.2	lb		4	"	"	57.4
			12.5 †	ln	"	"	81.
			11.7	l	"	11.7	89.
			09.1	l	"	"	39802.
			08.2	l	"	"	43.
			07.4	l	"	"	57.
05.804	05.84	3	05.82	6	"	"	70.
03.597		2		6	"	"	95.6
2498.873	2498.87	3	2498.82	6	"	"	39930.8
	96.78	1	96.7	2	"	"	40006.3
			93.2	l	"	"	41.0
			91.8	ln	"	11.8	97.
			91.3	ln	"	"	40120.
			89.5	4	"	"	28.
89.010	89.00	4	88.97	8	"	"	57.
	87.24	1	87.1	ln	"	"	64.8
86.618	86.61	3	86.58	6	"	"	96.0
			84.7	l	"	"	40203.5
			84.2	l	"	"	34.
				l	"	"	43.

† Double.

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
(Kayser)	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda}$	
			2423·5	1	0·72	12·2	41250·
			22·7	1	"	"	64·
			22·5	1	0·71	"	67·
2421·0	2420·	2b	21·2	1	"	"	93·1
18·835	18·82	2	18·80	4	"	"	41330·0
			16·7	1	"	"	66·
14·850	14·83	2			"	"	98·2
			14·7	4	"	"	41401·
			13·5	1	"	"	21·
			13·0	1	"	"	30·
			11·8	1n	"	12·3	50·
			11·5	1	"	"	56·
	09·79	1n	10·4	1	"	"	75·0
			08·7	2	"	"	41504·
	06·78	1	06·80	4	"	"	36·6
			04·8	1	"	"	71·
			03·3	1	"	"	97·
			01·5	2n	"	"	41628·
			00·9	1n	"	"	39·
			2399·2	1	"	"	68·
			98·0	1n	"	12·4	89·
			95·5	2	"	"	41732·
			90·8	1n	"	"	41815·
	2388·42	1	88·33	4	"	"	57·9
			86·5	1	"	"	90·
			85·8	1	"	"	41902·
			85·2	1	"	"	13·
			82·5	2	"	"	60·
			82·0	2	"	"	69·
			81·2	1	"	"	83·
			81·0	1	"	12·5	87·
			79·7	1	"	"	42010·
			79·4	1	"	"	15·
			78·7	1	"	"	27·
	78·00	1n	78·0	2	"	"	40·0
			75·5	1	"	"	84·
			74·7	1	"	"	98·
			73·8	1	0·70	"	42114·
2373·701		0			"	"	15·8
			73·0	1	"	"	28·
	72·24	2	72·13	4	"	"	43·7
			71·2	1	"	"	60·
			70·5	1	"	"	73·
			69·5	1	"	"	90·
68·044	68·05	2	68·00(Ir.)	1	"	12·6	42216·3
			66·3	1	"	"	47·
			64·7	2	"	"	76·
			63·7	1	"	"	94·
62·406	62·40	2	62·37	4	"	"	42317·1
	60·58	1	61·5	1n	"	"	33·
			61·0	1	"	"	42·
			59·5	1	"	"	69·
57·732	57·70	1	57·7	2	"	"	42491·0

‡ Double.

PALLADIUM—continued.

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo			
Kayser	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda} -$				
			2355.7	ln	0.70	12.6	42438.			
			55.2	1	"	"	47.			
			54.2	1	"	12.7	65.			
2351.428	2352.00 51.48	1	51.9	2	"	"	42506.0			
		2	51.4	2	"	"	14.7			
			50.8	ln	"	"	26.			
			48.7	1	"	"	64.			
			48.2	1	"	"	73.			
47.611	47.62	1	47.6	1	"	"	83.8			
			47.4	1	"	"	88.			
			45.0	1	"	"	42631.			
			44.4	1	"	"	42.			
			43.6	1	"	"	57.			
			41.0	1	"	"	42704.			
			39.7	1	"	12.8	23.			
			37.7	2	"	"	64.0			
36.663	36.66	2		"	"	83.0				
36.522	36.52	1	36.50	4	"	"	77.2			
			34.6	1	"	"	42821.			
			32.8	1	"	"	54.			
			32.6	1	"	"	53.			
	31.54	1	31.5	2	"	"	78.0			
			28.6	ln	"	"	42931.			
			28.3	1	"	"	37.			
27.575		0	27.5	1	"	12.9	50.3			
			23.5	ln	0.69	"	43026.			
			22.5	1	"	"	44.			
			22.1	1	"	"	51.			
			21.8	2	"	"	57.			
			19.7	1	"	"	96.			
19.328	19.35	ln				43103.0				
16.569	16.56	1	18.1	ln	"	"	26.			
			15.8	1	"	"	54.4			
			11.8	1	"	13.0	66.			
			09.5	1	"	"	43246.			
			08.5	2	"	"	86.			
			07.5	1	"	"	43305.			
			05.0	1	"	"	24.			
			02.14	1			71.			
						02.0	2	"	43427.0	
						2299.5	1	"	13.1	
						99.0	1	"	"	
				2296.61	3	96.52	4	"	"	43531.0
						95.1	ln	"	"	58.
						93.6	1	"	"	86.
						93.4	2	"	"	90.
	91.6	1	"			"	43624.			
	88.7	ln	"			"	80.			
	88.4	ln	"			13.2	85.			
	85.4	1	"			"	43742.			
	83.6	ln	"	"	77.					
	83.2	1	"	"	85.					
	82.6	1	"	"	96.					
	82.20	1	82.2	1	"	43804.0				
	80.92	1	80.9	1	"	29.0				

PALLADIUM--*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda} -$	
			2279.3	ln	0.69	13.2	43860.
			76.1	1	0.68	"	43922.
			75.5	1	"	13.3	33.
			75.0	1	"	"	43.
			74.5	1	"	"	52.
			73.4	1	"	"	74.
			73.0	ln	"	"	82.
			72.0	ln	"	"	44001.
			70.4	1	"	"	32.
			67.6	1	"	"	86.
			67.1	1	"	"	96.
	2264.40	1	64.5	1	"	"	44147.0
	62.59	1	62.7	2	"	13.4	82.0
			62.4	2	"	"	87.
			61.3	ln	"	"	44209.
			60.7	1	"	"	21.
			60.4	ln	"	"	27.
			59.6	1	"	"	42.
			59.2	1	"	"	50.
			58.7	1	"	"	60.
	54.40	ln					44344.3
			52.8	1	"	"	76.
			52.1	2	"	"	90.
	51.60	ln	51.5	2	"	"	44401.0
			49.6	1	"	13.5	39.
			49.0	1	"	"	51.
			48.4	1	"	"	63.
			48.1	1	"	"	68.
			47.1	1	"	"	88.
			45.5	1	"	"	44522.
			43.9	1	"	"	52.
			43.5	1	"	"	60.
			37.8	1	"	13.6	44673.
			35.3	1	"	"	44723.
			34.8	1	"	"	33.
	31.68	1	31.7	2	"	"	95.0
			29.3	2	0.67	"	44843.
			28.7	1	"	"	56.
			22.4	1	"	13.7	44983.
			21.5	1	"	"	45000.
			18.3	2	"	"	66.
			17.7	ln	"	"	78.
			15.3	1	"	"	45127.
			14.1	2	"	13.8	51.
			12.2	2	"	"	90.
			10.8	ln	"	"	45220.
			2198.2	ln	"	13.9	45478.
			97.5	1	"	"	92.
			85.7	ln	"	14.0	45738.
			84.7	1	"	"	59.
			82.4	1	"	"	45807.
			82.2		"	"	13.
			80.9		0.66	14.1	38.
			76.1		"	"	45940.
			74.5		"	"	73.

PALLADIUM—*continued.*

Wave-length Arc Spectrum		Intensity and Character	Spark Spectrum (Exner and Haschek)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser	Exner and Haschek				$\lambda +$	$\frac{1}{\lambda} -$	
			2173·4		0·66	14·1	45997·
			70·2		"	14·2	46065·
			64·5		"	"	86·
			62·4	1	"	"	46230·
			60·4		"	"	73·
			53·0		"	14·3	46432·
			52·4		"	"	45·
			49·3	1	"	"	46512·
			48·4	1	"	14·4	32·
			48·2	1	"	"	36·
			44·5	2	"	"	46616·
			31·5		0·65	14·5	46902·
			29·1		"	"	54·
			23·6	1	"	14·6	47175·
			17·7		"	"	47206·
			13·9		"	14·7	91·
			11·9		"	"	47336·
			02·0		"	14·8	47559·
			2098·2		"	"	47645·

On the Present Position of the Chemistry of the Gums.

By H. H. ROBINSON, M.A., F.C.S., F.I.C.

THE gums are a class of substances characterised by the property of either dissolving in water to form viscid solutions, or of absorbing water to form gelatinous pastes; these solutions or pastes, on exposure to air, lose their water, and dry to hard, translucent, somewhat glassy masses. The gums are uncrystallisable, and are composed of carbon, hydrogen, and oxygen. As found in nature they contain more or less ash constituents, and sometimes contain a little nitrogen. The nitrogen, if present, is small in amount, and is not regarded as an essential component, and this differentiates them from gelatin, glues and proteids, which also possess the above properties, but contain a considerable proportion of nitrogen.

The gums occur in plants, and are often found as exudations on the bark or other surfaces; some gums have also been found in animal products. Different views have been held as to the processes by which gum is formed in the plant. One view considers the production of gum part of the normal metabolism of the plant; in the case of tree gums they are generally regarded as an excretion resulting from the breaking down of cell tissue. In certain cases the formation has been attributed to the action of a fungus, which attacks the tree and generates an enzyme that penetrates the tissues and transforms the cell walls, &c., into gum. A third view attributes it to bacterial action, and it is claimed that specific bacteria have been found capable of producing different kinds of gum. The employment of a system of inoculating the trees to cause the production of gum has been suggested, but the evidence in support of it is as yet very slight.

The word 'gum' in its earliest use was probably applied to plant

exudations, which thickened and hardened on the surface of the plant, and thus it has been applied not only to substances which have an affinity for water, but also to resins and caoutchouc. As the latter are very different in their composition and properties from the substances of the class described above, it is most convenient not to include them with these.

One of the earliest recorded uses of the word is by Herodotus, who described, about 450 B.C., how in Egypt the embalmers swathed the corpse in strips of linen smeared with gum, which, he adds, the Egyptians generally use instead of glue; he employs the word κόμμι, from which the word 'gum' is descended. The gums have been familiar substances in European literature from that time to the present, being designated by some form or other of the word κόμμι, which itself was not a native Greek word, but was of foreign origin.

The views held regarding the chemistry of the gums since the year 1774, which may be regarded as the period of the dawn of modern science, have passed through three phases.

In the first phase they were regarded as being among the proximate or immediate principles of plants, such a proximate principle being defined as a distinct compound existing ready formed in plants. They were accordingly placed in the lists of such principles, which at that time were not very extensive. It was then imagined that the chemistry of animal and vegetable products was far simpler than we now know it to be. It was known that the gums were composed of carbon, hydrogen and oxygen, with possibly some nitrogen.

In the second phase, as analysis appeared to show that the hydrogen and oxygen were in the same proportions as in water, they were considered to be carbohydrates; and when, by studying the action of reagents on them, it was found that on hydrolysis they yielded various sugars, they were classed as polysaccharides—that is, substances formed of two or more sugar residues united together, and differing from the sugars by one or more molecules of water.

In the third phase, by a more careful and systematic series of fractionations and hydrolyses, several of the gum substances have been shown to be built up of the residues of sugar molecules, united by an ethereal oxygen attachment to an organic acid, which is different in different gums, and which may be regarded as the nucleus of the particular gum. In other words, they are glycosides of certain organic acids. The number of these sugar residues in a gum compound is considerable, and the natural gum is often a mixture of several gum compounds, differing from one another in the number of sugar residues in their molecules. As the attachment is ethereal, and not like that of an ester, the gum compounds possess acid properties, since the acid groups are not neutralised by the sugar residues.

This is the most modern view, and doubtless many, if not all, of the gums will be found to be of this nature when fresh examination of them has been made.

It must be understood, however, that these phases are not sharply marked off from one another in sequence of time, the germs of the later idea being often found in the records of earlier investigations.

In the early part of the nineteenth century a good many gums were known, the most familiar of which were gum arabic, gum tragacanth, gum Bassora, gums from the genus *Prunus*, such as cherry-tree gum,

and the mucilages or gum solutions obtained from linseed and from quince seed.

At that period the activity awakened by the new ideas in chemistry was the cause of various attempts to ascertain the nature of the substances that form the different gums. The work then done resulted in the descriptions of the properties of a few gum substances, believed to be individual chemical compounds, to which the names *bassorin*, *cerasin*, and *arabin* were given. After these names had been assigned, chemists, dominated by the idea that the number of organic compounds was only small, on investigating a gum identified its constituents with one or more of these substances. As these identifications rest on only a few simple properties, but little weight attaches to them. In fact, it now appears that the number of gum compounds is very considerable; consequently, in reading the literature of the last century, statements that the author had found the presence of arabin, or cerasin, or bassorin, &c., do not throw any certain light on the nature of the substance found, as it cannot be safely inferred that it is the same substance as the arabin, or cerasin, or bassorin, &c., found in another natural product by another author.

It may be of some interest to trace the origin of these names, so often attached in the last century to the components of the different gums.

Bassorin.—In 1811 Vauquelin published an examination of gum Bassora, and in the same year Pelletier, who was engaged in examining several gum resins, published a paper in which he proposed the name *bassorine* for the substance constituting the gum Bassora described by Vauquelin, since he believed he had found the same substance in the gum resins. Gum Bassora appears to be a gum having properties somewhat similar to those of tragacanth, but not to be so highly valued. It derives its name from the Turkish port now called Basra, at the head of the Persian Gulf, from which there is a considerable export of gums. A 'gum Bussora' is still quoted in the London market reports, but whether it is the same gum as that examined by Vauquelin, or whether it really comes from Basra, is not easy to say, since trade terms of the kind are often misleading.

Cerasin.—In 1812 John, who was aware of Vauquelin's work, published an examination of several gums derived from the genus *Prunus*, and gave the name of *cerasin* or *prunin* to the gum substance he obtained from the fruit of the plum known as Mirabel, and also from the stem of the wild cherry-tree, *Prunus avium*. He found that the gum of the sweet cherry-tree was of a different nature. The term 'prunin' did not come into use, but 'cerasin' has often been used.

Arabin and Para Arabin.—In 1833, Chevreul, in reporting on a memoir on the gums, written by Guérin, gave the name *arabine* to the gum substance of gum arabic and of gum Senegal, and remarked that if cerasin should prove to be identical in composition with arabin it ought to be called *para arabine*.

Roughly speaking, it may be said that in the descriptions of the gums the part soluble in cold water was put down as arabin, and the part insoluble in cold water was put down as cerasin or bassorin.

Metagummic Acid and Gummic Acid.—In 1860, Frémy published a paper in which he described a substance obtained by pouring a strong solution of gum arabic on to concentrated sulphuric acid. This substance is insoluble even in boiling water, but alkalis cause it to dissolve, and then acids do not reprecipitate it from the solution. He gave the name

metagummic acid to the insoluble acid, and *gummic acid* to the soluble acid produced by the action of alkalis on metagummic acid and also existing in soluble gum. He remarks that these experiments modified all the ideas then held concerning gum arabic, which up to then had been considered as a neutral substance comparable to dextrin, but that it now appeared that the natural gum was a lime salt of an acid. It was, in fact, gummate of lime, and the insoluble natural gum cerasin was metagummate of lime. It should be mentioned that the term 'gummic acid' has also been used for quite a different substance, prepared by Reichardt.

Arabic Acid.—That gum arabic was largely composed of an acid had already been discovered by Neubauer and announced in 1854 and 1857, although Frémy was not aware of this. Neubauer made analyses of the acid obtained by freeing gum arabic of its ash constituents and also of the salts of this acid, to which he gave the name *Arabinsäure*.

Metarabic Acid.—Frémy's term metagummic acid seems to have been changed into *metarabic acid* by later writers, no doubt because his gummic acid was the same as the arabic acid previously described by Neubauer.

As early as 1810 Gay-Lussac and Thénard had analysed gum, and had put it in the same class as sugar and starch, stating that these substances were composed of carbon united to hydrogen and oxygen, which were in the same proportions as in water; that is to say, they put it in the class of compounds now called 'carbohydrates.'

An important step in the elucidation of the problem of the constitution of gums was Scheibler's discovery, published in 1868 and in 1873, of a new sugar, *arabinose*, obtainable both from gum arabic and from a gummy substance yielded by sugar beet. He also noticed the concurrent liberation of an acid with the sugar, but does not seem to have investigated it further. As early as 1832, however, Guérin had obtained a sugar from gum arabic by the action of sulphuric acid.

Arabinon, galactose, xylose, fucose, and tragacanthose are other sugars which have been obtained from gums by hydrolysis.

Up till comparatively recently the gums have been placed among the carbohydrates, together with cellulose, starch, and dextrin, and have had the formulæ $(C_6H_{10}O_5)_n$ and $C_{12}H_{22}O_{11}$ assigned to them, and, in fact, this view has not yet been abandoned by the text-books. O'Sullivan, however, has shown that this view of their nature is mistaken, and that the gums are really acids of high molecular weight, and are constituted of an acid grouping forming a nucleus, to which are attached a number of the residues of various hexoses, pentoses, and bioses; these residues being linked on to the acid nucleus by an ethereal oxygen attachment, just as the dextrose and lævulose are joined in cane sugar. In some cases the linking is by two oxygen atoms, and reaction with two molecules of water occurs when the sugar residue is broken off by hydrolysis.

He first dealt with gum arabic, and in 1884 showed that it contained an acid nucleus of the formula $C_{23}H_{38}O_{22}$, to which in a later paper he gives the name *arabic acid*; it is the λ -*arabinosic acid* of the 1884 paper. The gum substance itself is an acid composed of this nucleus joined to the residues of a number of galactose and arabinose or arabinon molecules; arabinon, $C_{10}H_{18}O_9$, being a biose or disaccharide formed by the union of the residues of two arabinose molecules. On submitting the gum to hydrolytic action of varying degrees of intensity, more and more

of the sugar residues are split off and acids of lower and lower molecular weight and of higher and higher neutralising power are obtained, until arabic acid is reached. This acid is of considerable stability and requires strong hydrolytic action to break it up, and it then appears to suffer a great degree of disintegration. In the light of the pentose nature of arabinose announced in 1887 by Kiliani, O'Sullivan assigns to the gum substance the formula $2C_{10}H_{16}O_8$, $4C_{12}H_{20}O_{10}$, $C_{23}H_{38}O_{22}$, and names it *di-arabinan-tetragalactan-arabic acid*. In this 'arabinan' and 'galactan' stand for two molecules of arabinose and galactose respectively *minus* two molecules of water, the termination 'an' indicating the anhydride of the corresponding sugar. The arabic acid nucleus appears in this formula with four molecules of water less than in the free acid, indicating the occurrence of four double oxygen attachments between the sugar residues and the nucleus acid, and showing that sixteen molecules of water are required for complete hydrolysis to arabinose, galactose, and free arabic acid. In the natural gum, of course, the acid is more or less neutralised by the potash, lime and magnesia of the ash constituents of the plant. The 'arabic acid' of O'Sullivan thus denotes the nucleus acid, and not the acid of the natural gum substance; since the latter acid differs in different specimens of gum, this seems to be an advantageous change, especially as it permits of descriptive names being given to the varying natural gum acids.

A gum known in commerce as Geddah gum was next examined by O'Sullivan; it resembles gum arabic in being soluble in water, but it is dextrorotatory, whilst gum arabic is levorotatory. He found that it is a mixture of several gum acids, which are constituted of the radicles of galactose and of arabinose or arabinon, attached in considerable numbers to a nucleus acid to which the name *geddic acid* is given. Geddac acid is an isomer of arabic acid, $C_{23}H_{38}O_{22}$. The acids forming the mixture of which the gum itself is composed are of high molecular weight, and differ from one another in the number of arabinon molecules they contain and, consequently, in their rotatory power.

The third gum investigated was tragacanth. This, like Geddah gum, was found to be a mixture of several gum acids. It can be separated into a group of acids which remain in solution in dilute alcohol, and an insoluble portion, for which the old name *bassorin* is appropriated. The acids of the soluble group were found to be built up on a nucleus acid very similar, if not identical, with geddic acid, by its union with galactose and arabinose residues. The constitution of the insoluble portion, bassorin, has not yet been completely worked out, but it yields a nucleus acid of the formula $C_{14}H_{20}O_{13}$, to which the name *bassoric acid* is given, and intermediate acids formed of this acid united to the residues of xylose and of a new pentose sugar named *tragacanthose*.

It has been observed that in the case of the gum from sugar-beet the gum obtained in one season frequently differs in rotatory power from that obtained in another season, and that in the case of gum arabic different samples also differ in this respect. The explanation of this was discovered in the work on Geddah gum; the cause lies in the fact that in these varying gums the number of sugar residues attached to the nucleus acid varies, or in some cases it may be that the gums contain mixtures of the same gum acids, but in different proportions.

It was found that in a series of gum acids containing arabinans and galactans in varying numbers joined to geddic acid that there were

indications that the rotatory power varied fairly regularly in a series, thus :—

		<i>Series I.</i>	$[\alpha]_D$
Mon-arabinan-tri-galactan-geddic acid		+ 37°
Di- " " " " " "		+ 43°
Tri- " " " " " "		+ 49°
Tetra- " " " " " "		+ 59°
		<i>Series II.</i>	
Tri-arabinan-tetragalactan-geddic acid		+ 80°
Pent- " " " " " "		+ 90°
Hept- " " " " " "		+ 100°
Non- " " " " " "		+ 110°
		<i>Series III.</i>	
Tri-galactan-geddic acid		+ 20°
Tetra- " " " " " "		+ 22°
Penta- " " " " " "		+ 30°

The principal constants in identifying a gum acid are its ultimate composition, its neutralising power for bases, and its rotatory power for polarised light. As such acids do not crystallise, fractional precipitation must be resorted to in order to prove their individuality. Determinations of the amount of mucic acid they yield, and also of the amount of furfural, are helpful. In separating the nucleus acid, and in preparing intermediate acids lying between the natural gum acid and the nucleus, hydrolyses of varying intensity must be used, followed by precipitation with alcohol and purification by means of dialysis. Sometimes it is more convenient to precipitate as barium salts instead of as the free acids.

There is no doubt that in future work on the gums the methods adopted by O'Sullivan should be followed, and that a determination not only of the sugars they yield should be made, but also of the nature of the nucleus acid. In fact, a great deal of investigation is required to bring our knowledge of other gums up to the level of O'Sullivan's discoveries in the case of gum arabic, Geddah gum, and tragacanth.

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The Present Position of the Chemistry of Rubber.
By S. S. PICKLES, M.Sc.

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INDIARUBBER, or caoutchouc, is a hydrocarbon which is present in the milky juices of various trees and shrubs, belonging chiefly to the natural orders Euphorbiaceæ, Moraceæ, Artocarpaceæ, and Apocynaceæ. The milky juice, technically known as latex, and which exudes from certain plants when wounded, is quite distinct from the so-called sap of plants. It is contained chiefly in the middle layer of the bark, in a network of minute tubes known as laticiferous vessels. These vessels run for the most part longitudinally in the other plant tissues, forming usually a closed and connected system.

The latex possesses to some extent the properties of a vegetable emulsion, the caoutchouc being suspended in it in the form of minute transparent globules averaging about $\frac{1}{12250}$ inch in diameter (Adriani). On coagulation by means of heat, or treatment with various chemicals, the coagulum consists largely of the indiarubber hydrocarbon, mixed, however, with certain quantities of resinous and albuminoid substances. The proportion of resinous matter varies in different varieties of latex, and depends upon the botanical source, habitat, and age of the plant, and also upon the portion of the plant from which the latex was taken.

The botanical function of the latex forms a very interesting and important study, and much has been written regarding this portion of the subject; this, however, falls outside the province of the present report, which is intended to be confined as closely as possible to the pure chemistry of the indiarubber hydrocarbon.

When pure, indiarubber is an almost colourless, elastic substance, and when obtained in thin sheets is quite transparent; the specific gravity varies slightly in different samples between .91 and .93.

It belongs to that class of substances known as colloids, and this fact makes the investigation from a chemical standpoint a matter of considerable difficulty. Even dilute solutions are gelatinous in nature, and it is almost impossible to prepare definite and characteristic derivatives direct from the hydrocarbon. Its analysis shows it to have the composition expressed by the empirical formula C_5H_8 , though its molecular weight is probably many multiples of this number; it is an unsaturated hydrocarbon, having one unsaturated bond or double linking for every complex C_5H_8 . On heating it is decomposed, giving a mixture of hydrocarbons, most of which have the same empirical composition as the parent rubber. The earlier work on the chemistry of indiarubber was almost entirely confined to the examination of the products obtained by destructive distillation, and it is proposed to devote the first part of the report to an historical survey of these investigations.

The first mention of indiarubber on record was made about four hundred years ago by Herrera,¹ who, in his account of the second voyage of Columbus to America (1493-1496), observed that the inhabitants of

¹ *Encyclopædia Britannica*, vol. xii. 1881, p. 835.

Hayti played a game with balls made from the gum of a tree, and that the balls were lighter and bounced better than the wind balls of Castile.

Torquemada, in 1615,¹ described the tree yielding this gum as one which the Mexican Indians called Ulequahuitl, and although there is much doubt about the point, it has been regarded as identical with the tree now known as *Castilloa elastica*. Torquemada also mentioned that an oil was obtained by the action of heat on the rubber, which was used for various medicinal purposes. The Spaniards, even at this early date, used the juice of the tree to waterproof their cloaks.

No rubber seems to have reached Europe, however, till a much later date.

La Condamine, the celebrated French explorer, was the first to give any accurate information regarding rubber trees (about the year 1735). In 1751 the subject is again mentioned in the researches of M. Fresneau, published by the French Academy, and M. Aublet, in 1755, described a caoutchouc-yielding tree occurring in French Guiana. Such trees were also described by J. Howison (1798), and later Roxburgh showed that Assam rubber was the product of the tree *Ficus elastica*.

Berniard,² in 1781, described the processes of the collection and working up of indiarubber, and mentioned the oil which is formed from it by dry distillation.

Priestley alludes to the use of indiarubber as an erasing material in his work on 'Perspective,' and the oil obtained from indiarubber is again mentioned in Fourcroy's 'Système de Connaissances Chimiques,' published in 1790.

*Investigations on the Products of the Destructive Distillation of Indiarubber.*³

In the year 1833 W. H. Barnard,⁴ in the course of some experiments at the works of Messrs. Enderby, at Greenwich, observed that when caoutchouc was exposed to a temperature of about 600° F. (315° C.) it was resolved into a vapour, which on cooling condensed to a liquid having remarkable properties, and to which the name caoutchoucine was given. Barnard obtained a patent in August 1833⁵ for this invention 'of a solvent not hitherto used in the arts.' In the specification the process of preparation is indicated, and a diagram is given of the cast-iron still and water-cooled worm condenser used in the distillation. The still was slowly heated until the temperature registered had risen to 315° C., and during this period a dark-looking liquid distilled over, which Barnard claimed as his invention, the liquid being a solvent of caoutchouc and resinous and oleaginous substances. He afterwards rectified this liquid and obtained fractions varying in specific gravity, of which the lightest was not below .670.

He stated that at each rectification the oil became more bright and

¹ *Loc. cit.*

² Rozier, *Observations et Mémoires sur la Physique*.

³ The author acknowledges his indebtedness to the concise collection of the literature on this subject, published by Dr. R. Ditmar, Graz, in the *Gummi Zeitung*, 1904.

⁴ Dr. Ure's *Dictionary of Arts, &c.*, 1853, p. 358.

⁵ Specification No. 6466, August 20, 1833.

transparent, until at a specific gravity about $\cdot 680$ it was perfectly colourless and highly volatile. In the specification Barnard also gives practical instructions for the distillation, the cleaning out of the still by means of solder, and the removal of the obnoxious odour from the oil. The oil was used as a solvent for caoutchouc, resins, varnishes, and paints, and for mixing with cocoanut oil to render it suitable for burning in lamps. No definite boiling-point was given, so it must be presumed that the term caoutchoucine included all the lighter and lower boiling portions of the oil.

In 1834 Beale and Enderby¹ prepared the oil in large quantity. They are stated to have obtained by the distillation of rubber $83\frac{1}{2}$ per cent. of an oil of specific gravity $\cdot 640$ and boiling below 38° C. This statement occurs in 'L'Institut,' 1834, and was copied from there into the 'Jahresberichte' of Berzelius, xv. 320 (1836). The process here referred to may be the one for which Barnard was granted a patent in 1833, particularly as he was working at the works of Messrs. Enderby. The yield of the light oil, however, is obviously erroneous.

In 1834 J. T. Beale, of Whitechapel, obtained a patent for a new form of lamp (Specification No. 6537), in which it was proposed to burn 'liquids, including any of the fluids of the distillation and occasional rectification of indiarubber.'

The oil caoutchoucine was analysed quantitatively by Dumas, who found it to be composed of carbon and hydrogen in the proportions C = 88 per cent., H = 12 per cent. In the 'Annalen de Chimie u. Pharm.' for 1835, Liebig, in an article entitled 'A Note concerning the Purification of Products obtained by the Dry Distillation of Organic Materials,' describes an oil which 'Dr. Gregory had obtained in large quantity by the distillation of rubber.' Liebig states that on rectification the boiling-point of the oil rose slowly from 35° to 65° , that the specific gravity was $\cdot 673$, and was composed of carbon and hydrogen only. The oil, distilling at 36° , reduced sulphuric acid with the evolution of sulphur dioxide and the formation of black colour. On afterwards adding water to the product of the acid treatment, an oil was obtained which, after rectification, boiled at 220° .

In 1836 Gregory² published his own investigations in an article entitled 'Concerning a Volatile Oil obtained from Indiarubber by Destructive Distillation, with Notes concerning some other Empyreumatic Substances.'

By repeated rectification Gregory obtained liquids, boiling from about 32° C. (not constant) to 77° C., which had a specific gravity of $\cdot 666$ at $15^{\circ}\cdot 5$. He found that this product was not identical with an oil known as 'eupion,' previously described by Reichenbach,³ as it was at once destroyed by sulphuric acid. Gregory also isolated from the distillate the fractions mentioned by Liebig, the figures varying slightly, however, from those given by the latter chemist. He stated that he obtained a highly rectified oil boiling at 96° F. ($35\cdot 5^{\circ}$ C.), specific gravity $\cdot 670$, which on treatment with sulphuric acid yielded an oil, boiling-point 220° , and which had the same composition as oil of turpentine (C_5H_8 or $C_{10}H_{16}$). Some of the oils obtained boiled as high as 360° C.

¹ *L'Institut*, 1834, p. 290.

² *London and Edinburgh Phil. Mag. and Journ. of Science*, Third Series, vol. ix. (1836), p. 322.

³ *Ann. de Pharm.*, 8, 217 (1833).

On October 14, 1834, John Dalton read a paper before the Manchester Literary and Philosophical Society 'Concerning certain Liquids obtained from Caoutchouc by Dry Distillation.' The paper did not appear in print, and it was not until 1836 that the contents of the paper were published.¹ The liquids (contained in four phials) examined by Dalton had been submitted to him by an unknown friend, and he believed them to be the results of successive distillations.

No. 1 contained a dark coloured liquid, specific gravity $\cdot 86$.

No. 2 contained a slightly coloured liquid, specific gravity $\cdot 837$, boiling-point 143° – 166° .

No. 3 contained a colourless liquid, specific gravity $\cdot 752$, boiling-point 60° .

No. 4 contained a liquid, specific gravity $\cdot 68$, boiling-point 42° .

He found that the vapour tension of No. 4 was practically the same as that of sulphuric ether. Their relative volatilities were examined by plunging the bulbs of thermometers into the liquids, and then observing the fall of temperature on evaporation. He determined the specific gravity of No. 4, and found it to be $2\cdot 07$ (air=1). Dalton considered that the oil No. 4 was identical with that obtained by Faraday by the decomposition of oils by heat, but also that it was capable of further rectification.

A. F. C. Himly, in 1835, published his dissertation (Göttingen) entitled 'De caoutchouc ejusque distillationis siccae productis et ex his de cautchine, novo corpore ex hydrogenio et carboneo composito,'² and seems to have gone very fully into the question of the decomposition products of indiarubber. He obtained on distillation of speck rubber 75 per cent. of an ethereal oily distillate of specific gravity $\cdot 8702$, and from this he separated a portion boiling 56° to 96° C., which, when carefully redistilled, gave a very volatile oil having the following properties: specific gravity, $\cdot 654$; boiling-point, 33° – 44° C. It was completely transparent, and had a pleasant odour, was not solidified at a temperature of -39° , and on evaporating on the bulb of a thermometer reduced the temperature from $+20^{\circ}$ to -10° . This oil was named 'Faradayin' by Himly, because it possessed great similarity to an ethereal liquid obtained about that time by Faraday by the distillation of an oil, although the boiling-point of Faraday's liquid was 10° higher than that obtained by Himly. Among other fractions obtained by Himly was one boiling $171^{\circ}\cdot 5$, to which he gave the name 'cautchine.' By redistillation of this he obtained a liquid, boiling-point 168° – 171° , which he purified as follows: It was first dried with calcium chloride, and converted into cautchine hydrochloride by passing dry hydrogen chloride gas into the well-cooled liquid. The product was dissolved in alcohol and reprecipitated with water, dried with CaCl_2 , and the hydrochloric acid split off by distilling over quicklime or barium oxide, the resulting liquid being distilled over potassium. The hydrocarbon thus obtained had the following properties: It was a clear neutral oil, only slightly refractive, and possessed an odour and taste resembling those of orange oil; specific gravity, $\cdot 8423$ at 16° ; boiling-point, $171^{\circ}\cdot 5$ at 750 mm.; did not solidify at -39° , and was soluble in absolute alcohol, ethereal and fatty oils, and carbon disulphide.

¹ *London and Edinburgh Phil. Mag. and Journ. of Science*, Third Series, vol. ix. 1836), p. 479.

² *Ann. d. Ch. u. Pharm.* 27, 41.

The vapour density indicated the formula to be $C_{10}H_{16}$, and it gave on analysis the following figures:—

C = 87.00 per cent.	H = 11.56 per cent.
Calculated ° for $C_{10}H_{16}$.	
C = 88.23 „	H = 11.77 „

Himly also described chlor-caoutchine obtained by passing chlorine into the cooled hydrocarbon, and also the caoutchine hydrochloride obtained by the action of dry hydrochloric acid gas on cooled caoutchine.

The most complete investigation of this period on the distillation products of rubber was that made by Alexander Bouchardat, and published in 1837 in the 'Journal de Pharmacie' (vol. xxiii. 1837).

The object of the investigation was the discovery of a good solvent for indiarubber. Bouchardat distilled his rubber from a copper retort fitted with a curved neck which terminated in a spiral condenser. This was surrounded by ice, and communicated at the base with a series of three bottles immersed in a freezing mixture. By distillation in this apparatus 417 grs. of rubber yielded (a) 357 grs. of liquid, collecting in the first flask, and (b) 29.82 grs. in the other two flasks.

Hevéène.

From the liquid in the first flask Bouchardat isolated a hydrocarbon boiling at $252^{\circ} C.$, to which he gave the name hevéène (from *Hevea guianensis*, a euphorbiaceous rubber-yielding tree). This is a transparent, neutral yellow oil, having a specific gravity .921 at 16.8° , and boiling point about 252° . It does not solidify at low temperatures, burns with a smoky flame, and is soluble in absolute alcohol. The composition in two experiments was found to be:—

1. C = 86.62	H = 13.18
2. C = 85.24	H = 14.76

This substance forms a wax-like derivative when chlorine is passed over it, hydrochloric acid being at the same time evolved. Bromine and iodine compounds were also obtained, but evolution of HBr or HI always accompanied the formation. When treated with strong caustic potash or soda hevéène becomes viscous and discoloured owing to oxygen absorption. On slowly adding strong sulphuric acid to hevéène in a stoppered flask—with frequent cooling—Bouchardat obtained a thick brown mass, and noticed that after standing a few days a clear oily liquid floated on the top. This oil was separated, washed, purified, and finally distilled. It boiled at $182^{\circ}.4$, was soluble in alcohol and ether, and was unacted upon by concentrated alkalies and acids.

Bouchardat considered it to be identical with the product obtained by Gregory by treating the light oil (boiling-point 35° – 77°) with sulphuric acid, although Gregory's product boiled at $226^{\circ} C.$

On examining the liquid contained in the second and third flasks, it was found to be a transparent, mobile, slightly yellow liquid, which boiled a few degrees above freezing-point. A portion crystallised out at $-25^{\circ} C.$, but the other part of the liquid would not solidify at -30° . A partial separation was thus effected: (a) the mother liquid was run off and examined first. On acting upon it with sulphuric acid, heat was developed, and after standing for a few days a clear transparent oil separated

This, after washing with potash, distilled at $63^{\circ}7$ at 745 mm. It was a colourless liquid, specific gravity $\cdot 69$ at $18^{\circ}75$, insoluble in water, and unacted upon by acids. Bouchardat compared it with Reichenbach's 'eupion.' (b) By warming the original liquid to $12^{\circ}5$ and condensing the vapour in a freezing mixture a liquid was obtained boiling below 0° and having a specific gravity $\cdot 65$ at -5° . It was soluble in ether and alcohol. On the addition of concentrated sulphuric acid it gave a brownish coloured product, which was not acted upon by potash or hydrochloric acid. It boiled at $85^{\circ}5$ C. and had a specific gravity $\cdot 85$ at $15^{\circ}5$. Bouchardat considered it to be identical with Faraday's then recently discovered hydrocarbon,¹ now known as benzene. (c) After the liquid boiling below 0° had been collected, a fraction was obtained boiling between $12^{\circ}5$ and $22^{\circ}5$. From this liquid, on cooling in a freezing mixture, a solid separated in the form of fine white needles. These were separated from the adhering liquid, and on examination Bouchardat found the substance to be a hydrocarbon, to which he gave the name caoutchene. It forms a white opaque mass, melting-point, $-12^{\circ}5$; boiling-point, $18^{\circ}12$ at 752 mm.; specific gravity, $\cdot 65$ at $-2^{\circ}5$; soluble in alcohol, and is not acted upon by alkalis.

Analysis gave the figures :—

1. C = 85.09 per cent.	H = 13.77 per cent.
2. C = 85.44 „ „	H = 14.59 „ „

The treatment of this subject, however, on modern scientific lines, and the isolation of definite compounds from the distillation products of rubber, may be said to date from 1860, when Greville Williams² continued the work of Himly and Bouchardat. Williams distilled the india-rubber in an iron alembic, using the lowest temperatures consistent with the distillation, and the process was stopped before all the hevéène fraction had passed over. The distillate possessed an unpleasant odour, due, he considered, to the volatile bases resulting from the decomposition of the vegetable casein in the rubber. By purification and redistillation he separated two chief fractions from the oil, (1) boiling at 37° – 44° C., and (2) boiling at 170° – 180° C. These same fractions appear to have been also isolated about the same time by Williams from the distillation product of gutta-percha.

Isoprene.

No. 1, after careful rectification over sodium, boiled almost entirely between 37° and 38° . It had a vapour density of 2.44 (air=1) (calculated for $C_5H_8=2.45$), and specific gravity $\cdot 6823$. The mean of three analyses of the liquid obtained both from rubber and gutta-percha gave the figures :—

C = 88.0	H = 12.1
Calculated for C_5H_8	
C = 88.2	H = 11.8

He gave to this liquid the name 'isoprene.' Williams observed that this isoprene, when left in a bottle for some months, became sticky, lost its fluidity, and became 'ozonised' (peroxidised) by absorbing the oxygen of the air. The peroxidised isoprene possessed marked bleaching

¹ *Phil. Trans. Royal Soc.*, 1825.

² *Proceedings Royal Society*, 1860, p. 517.

properties, decolouring indigo sulphate and converting lead sulphide into lead sulphate. By careful distillation of this sticky product some isoprene first passed over; the temperature then rose quickly, and the residue was converted into a white spongy mass, which consisted of carbon, hydrogen, and oxygen. Analysis gave:—

C = 78·7	H = 10·7	O = 10·5
Calculated for $C_{10}H_{16}O$		
C = 78·94	H = 10·52	O = 10·54

Isoprene also readily combined with bromine, the action being somewhat violent.

Caoutchine.

Fraction No. 2. The portion boiling at 170° – 180° was further rectified, and Williams obtained a fraction boiling almost constantly at 170° – 173° , which was identical with the caoutchine obtained by Himly (boiling at 171°).

Gutta-percha also yielded the same fraction, and the mean of the analyses of samples from both sources gave:—

	C = 88·1	H = 11·9
Himly's figures	C = 88·4	H = 11·56

Greville Williams showed that the vapour density of caoutchine was double that of isoprene, and observed that it belonged to a group of substances isomeric with turpentine-oil, the same quantity of bromine being absorbed by it as by turpentine-oil. He described the preparation of the bromide, and on distillation of this brom compound with potassium he obtained an oil boiling at 170° – 200° , which he considered to be cymene. On oxidation with sulphuric acid and potassium dichromate, this oil gave an acid apparently identical with the isolinic acid obtained by Hofmann. An oil boiling at 300° was also produced, which Williams termed paracymol.

On treating caoutchine with an excess of concentrated sulphuric acid there resulted a thick liquid from which, on treatment with lime, Williams obtained a calcium salt of the empirical formula $C_{20}H_{15}CaS_2O_6$.

Isoprene, thus obtained by Williams, was afterwards the subject of further investigations by M. G. Bouchardat.¹ On heating isoprene in a sealed tube containing carbon dioxide for ten hours at 280° – 290° Bouchardat obtained a viscous sticky mass which no longer boiled at 38° .

On distillation this gave (1) some unchanged isoprene; (2) an inactive hydrocarbon boiling at 170° – 185° , having an odour like lemons, specific gravity $\cdot 866$ at 0° , and composition $C_{10}H_{16}$; (3) other higher boiling condensation products.

The hydrocarbon boiling at 170° – 185° was optically inactive and absorbed oxygen from the air. Bouchardat found that it combined with hydrogen chloride in ethereal solution, giving two different compounds—(1) a hydrochloride boiling at 145° (100 mm.), having the composition $C_{10}H_{16}HCl$; and (2) a solid dihydrochloride melting at $49^{\circ}\cdot 5$, having the formula $C_{10}H_{16}2HCl$.

The name of di-isoprene was given to this hydrocarbon, a polymer of isoprene, the boiling-point of which was found to be $174^{\circ}\cdot 6$. Bouchardat

¹ *Comptes Rendus*, lxxxix. p. 1117 (1879).

considered it identical with terpine, the optically inactive hydrocarbon of turpentine oil, the dihydrochloride being identical with terpine hydrochloride. He also suggested the identity of this di-isoprene with caoutchine and with the hydrocarbon from terebinthine, as he was able to obtain terpine hydrate from all three.

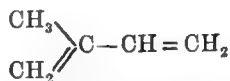
Subsequently Bouchardat investigated the action of hydrogen chloride and hydrogen bromide on isoprene itself, and found that here also, two hydrochlorides and hydrobromides were produced by the addition of one, or two, molecules of the halogen acid. The following compounds were prepared:—

	Boiling-point.	Specific Gravity.
C_5H_8HCl . . .	85°-91°	0.868 at 15°
$C_5H_8_2HCl$. . .	145°-953°	1.065 at 16°
C_5H_8HBr . . .	104°-108°	1.173 at 15°
$C_5H_8Br_2$. . .	175°-180°	1.601 at 15°

as were also several other halogen compounds and their derivatives.

A very interesting observation was also made by Bouchardat, viz., that on treating isoprene with cold aqueous hydrochloric acid, saturated at 0° C., an elastic polymer was obtained, which after boiling with water possessed the properties of indiarubber. It had the same percentage composition as isoprene, was insoluble in alcohol, swelled upon treatment with ether, and dissolved in carbon disulphide like indiarubber. On dry distillation the same hydrocarbons are produced as in the case of caoutchouc. One of these, $C_{10}H_{16}$, was isolated, and was identical with a similar hydrocarbon obtained from caoutchouc, yielding on treatment with hydrogen chloride a solid hydrochloride melting at 46°.

If this substance obtained by Bouchardat was really indiarubber, this work constitutes the first partial synthesis of this hydrocarbon. The isoprene used was, however, itself obtained from rubber. This same elastic polymer was subsequently obtained by Professor W. A. Tilden,¹ in 1882, with isoprene from other sources. By passing turpentine oil through a red-hot tube and fractioning the products of decomposition, Professor Tilden isolated a small quantity of a liquid, boiling-point 37° the vapour density of which corresponded with the formula C_5H_8 , and which was apparently identical with isoprene. On treating this with concentrated hydrochloric acid he obtained a tough elastic product closely resembling caoutchouc. Isoprene from rubber was also examined by Tilden, who confirmed Bouchardat's observations, except that he found the boiling-point to be 35°. He also obtained the elastic polymer by treatment with nitrosyl chloride, and prepared isoprene tetrabromide $C_5H_8Br_4$ for the first time. In his publication Tilden also discussed the question of the constitution of isoprene, and concluded that isoprene is β methyl crotonylene



a view which has since received synthetical confirmation.

Dr. O. Wallach,² in 1885, conducted a thorough investigation of the hydrocarbons, caoutchine and isoprene, obtained by the distillation of

¹ *Chem. News*, 1882, pp. 120-121; *Brit. Assoc. Report, Southampton*, 1882.

² *Ann. der Chem.*, 1885 (227), pp. 292-296; 1884 (225), p. 311.

rubber. After distilling off the low boiling portions of the distillate, Wallach subjected the remainder to distillation in steam, and thus obtained a liquid boiling after rectification at 180° , the 'caoutchine' of Himly, Williams, and Bouchardat. On treatment with bromine this gave a solid tetrabromide, melting-point 125° - 126° , which proved to be completely identical with the tetrabromide of the hydrocarbon then known as cinene (now dipentene). The solid hydrochloride was also obtained, melting at 49° - 50° , from which by treatment with aniline Wallach regenerated the caoutchine. From the identity of the tetrabromides, and of the odours, he concluded that caoutchine and cinene (dipentene) were identical.

The isoprene, boiling-point 34° - 39° , was also examined by Wallach,¹ who confirmed the observations of Bouchardat and Tilden on the polymerisation to di-isoprene on heating, and showed by means of the tetrabromide that this also was identical with caoutchine and cinene. Wallach seems to have been the first to notice the spontaneous conversion of isoprene into a rubber-like product simply by the action of light. He allowed isoprene to remain in a sealed tube in the light for a long time, and on afterwards adding alcohol to the liquid a tough indiarubber-like mass separated out which, on standing in the air for some time, resinified. In May 1892, Professor Tilden² read a paper before the Philosophical Society of Birmingham, in which he makes the following statement with regard to the spontaneous conversion of isoprene into caoutchouc, being apparently unaware of Wallach's observation:—

'Specimens of isoprene were made from several terpenes in the course of my work on those compounds, and some of them I have preserved. I was surprised a few weeks ago at finding the contents of the bottles containing isoprene from turpentine entirely changed in appearance. In place of a limpid colourless liquid, the bottles contained several large masses of a solid of a yellowish colour. Upon examination this turned out to be indiarubber. The change of isoprene by spontaneous polymerisation has not, to my knowledge, been observed before. I can only account for it by the hypothesis that a small quantity of acetic or formic acid had been produced by the oxidising action of the air, and that the presence of this compound had been the means of transforming the rest. The liquid was acid to test paper, and yielded a small portion of unchanged isoprene.

'The artificial rubber, like natural rubber, appears to consist of two substances, one of which is more soluble in benzene or in carbon disulphide than the other. A solution of artificial rubber in benzene leaves on evaporation a residue which agrees in all characters with a similar preparation from Para rubber. The artificial rubber unites with sulphur in the same way as ordinary rubber, forming a tough elastic compound.'

Bouchardat and Lafont,³ in 1886, treated caoutchine with glacial acetic acid, and obtained terpineol acetate, $C_{10}H_{16} \cdot C_2H_3O_2$, boiling-point 220° , or 110° - 115° (10 mm.) Specific gravity, 0.9570 at 18° C. It is inactive, and on hydrolysis with hydrochloric acid gave caoutchine dihydrochloride and acetic acid.

By saponification of the acetate with alcoholic potash at 100° inactive terpineol is formed, which, when crystallised by cooling, afterwards melts at 32° .

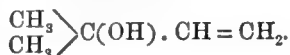
¹ *Ann. der Chem.*, 1887 (238), pp. 88-89.

² *Chem. News*, vol. lxx., p. 265.

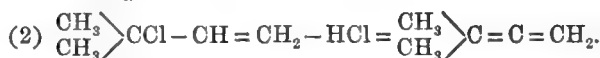
³ *Ann. Chem. Phys.*, 1886, pp. 507-534.

This boils at 114°–118° (10 mm.), and on treatment with hydrogen chloride gas gives the same dihydrochloride as above, $C_{10}H_{16}2HCl$, shown by Wallach to be identical with dipentene hydrochloride. The formation of these compounds furnishes additional proof of the identity of caoutchine with dipentene.

We have seen that in 1882 Tilden suggested that isoprene was β methyl crotonylene, but brought forward no other experimental proof than that on oxidation it yielded carbonic, formic, and acetic acids. Gadziatzky¹ was the first to bring forward direct experimental proof in the support of this formula for isoprene. From isoprene hydrochloride he obtained a tertiary alcohol, dimethyl-vinyl carbinol—

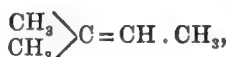


He also showed that on heating isoprene with dilute alcoholic hydrochloric acid it is transformed into dimethylallene, which change can be represented as taking place by the alternate addition and elimination of hydrochloric acid :—

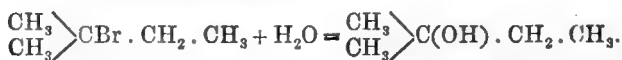
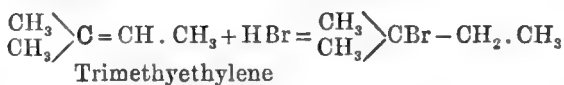


Mokiewsky² in 1895 succeeded in obtaining a solid crystalline derivative of isoprene by the action of hypochlorous acid upon it. This melted at 81°, and he considered it to have the formula $C_5H_8(OH)_2Cl_2$ (isoprene dichlorhydrin).

Ipatieff and Wittorf³ (1897) identified amongst the products of rubber distillation the hydrocarbon trimethyl ethylene,



after Mokiewsky⁴ had shown it to be present in the distillation products of the turpentine decomposition. This occurs in the fraction 33°–38° of the rubber distillate. On treating this fraction with HBr in acetic acid solution a hydrobromide was obtained, boiling-point 50°–74° (16 mm.). On treatment with water and potassium carbonate this gave an oil which proved to be dimethyl ethyl carbinol. Its formation from trimethyl-ethylene is expressed in the following manner :—



Dimethylethyl carbinol.

The chief product of the treatment of the 33°–38° fraction with

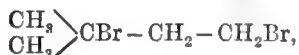
¹ Wolkow, *Journ. of Russian Phys. Chem. Soc.*, **20**, 706.

² Mokiewsky, *Chem. Zeit.*, 1895, 101.

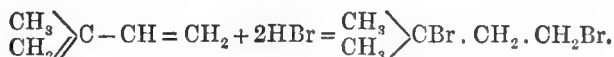
³ *Journ. f. Prakt. Chem.*, 1897, pp. 2–3.

⁴ *Journ. Russ. Phys. Chem. Soc.*, **27**, 516.

HBr, however, is β dimethyl trimethylene bromide; specific gravity, 1.696 at 0°

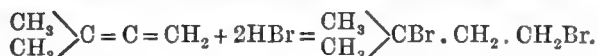


which was shown to be identical with the bromide obtained from β dimethyl allene (Gadziatzky). Assuming that isoprene possesses an open chain, these results are best explained by supposing that isoprene has the formula proposed by Tilden, and which Ipatieff called methyl divinyl.

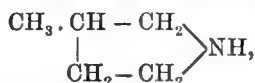


β methyl crotonylene (Tilden),
or isopropenyl ethylene (Gadziatzky),
or as-methyl divinyl (Ipatieff).

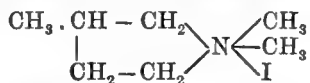
The preparation from β dimethyl allene is expressed—



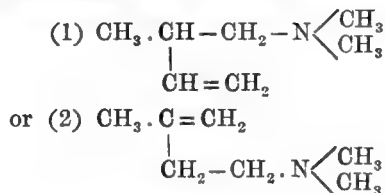
The question of the constitution and formula of isoprene was, however, settled beyond doubt by the synthesis, in 1897, of β methyl crotonylene by Euler¹, who found it to be identical in properties with isoprene. Euler started with β methyl pyrrolidine,



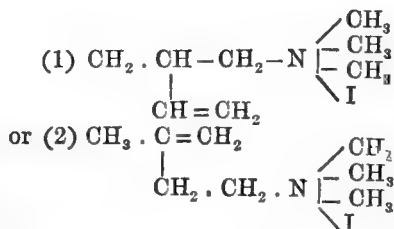
which, on treatment with methyl iodide and potassium hydroxide, was converted into β methyl-dimethyl-pyrrolidyl-ammonium-iodide:—



On distillation with solid potash this is converted into one of two bases, both yielding the same end results:—

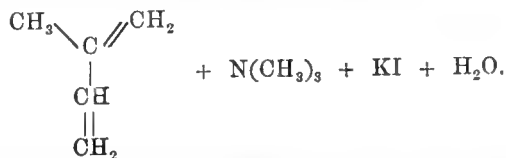


On again treating with methyl iodide these bodies yield respectively the compounds:—



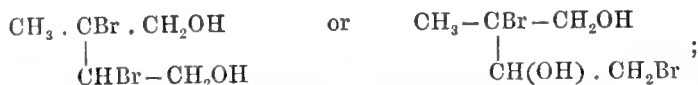
¹ Ber., 30 (1897), pp. 1989-91.

both of which on distillation with solid potash split up and give isoprene, trimethylamine, potassium iodide, and water :—

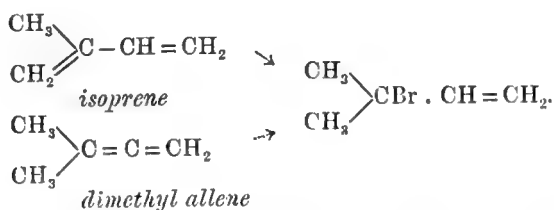


The isoprene thus prepared was found to be identical with the isoprene obtained from caoutchouc. It was identified by means of the hypochlorous acid addition product, melting-point 81° , isoprene dichlorhydrin, obtained by Mokiewsky.

In 1898 Mokiewsky¹ prepared an isoprene dibromhydrin similar to the above dichlorhydrin, and having probably the constitution—



and in 1899² this same investigator showed that on attaching a molecule of hydrogen bromide to isoprene the same unsaturated tertiary bromide is obtained as from dimethylallene when similarly treated. This furnishes additional confirmation of the correctness of the isoprene formula :—



Composition of Caoutchine, Di-isoprene, or Dipentene.

We have seen that Wallach had proved conclusively the identity of di-isoprene, the polymerisation product of isoprene, obtained by Bouchardat and Tilden, with the hydrocarbon known as cinene or dipentene, and that the caoutchine of Himly and Williams was also identical with this substance. The constitution of dipentene, however, for a long time remained a matter of much uncertainty.

Dipentene is one of the most commonly occurring terpenes, being found free in nature, and being also easily prepared from many other naturally occurring products, such as terpineol and pinene. It is an inactive hydrocarbon, but is really an externally compensated mixture of two active hydrocarbons, the *d* and *l* limonenes. Tilden³ showed that it was closely related to the alcohol terpineol $\text{C}_{10}\text{H}_{18}\text{O}$, and Wallach⁴ found that on heating terpineol with potassium bisulphate at 200° water was eliminated and dipentene was formed. Wagner, in 1894,⁵ after a

¹ *Journ. Russ. Phys. Chem. Soc.*, **30** (1898), pp. 885-900.

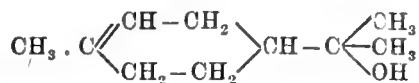
² *Ibid.*, **32** (1899), pp. 207, 216.

³ *Ber.*, 1879, **12**, 848.

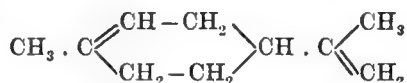
Ann. (1885), **230**, p. 258.

⁵ *Ber.*, **27**, 1636.

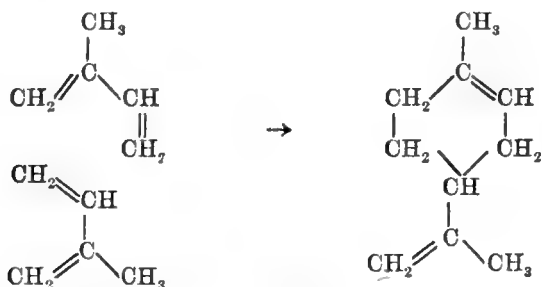
careful consideration of the relationship of terpineol to pinene, pinol, and sobrerol, deduced the formula



as best representing terpineol, and represented the constitution of dipentene as

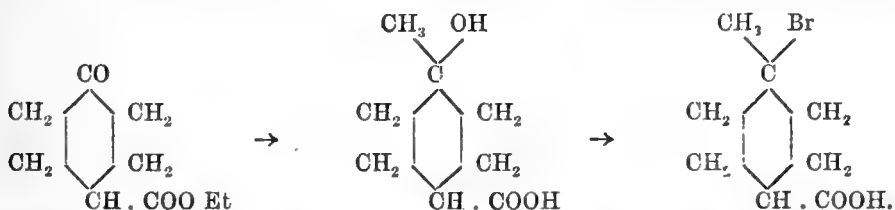


Ipatieff¹ suggested the probable formation of dipentene from isoprene by the condensation of two molecules of the latter in the following manner:—

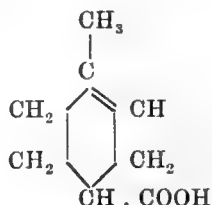


The proof of the correctness of Wagner's formula for dipentene was supplied by Professor W. H. Perkin, jun.,² in 1904, by his synthesis of terpineol and dipentene from δ keto hexahydrobenzoic ester.

This ester, after treatment with magnesium methyl iodide and subsequent hydrolysis, yields δ hydroxy hexahydro *p*-toluic acid, which on the addition of fuming HBr passes into δ brom-hexa-hydro-*p*-toluic acid.



Weak alkalis or pyridine eliminate HBr from this acid, yielding Δ^3 tetrahydro-*p*-toluic acid.

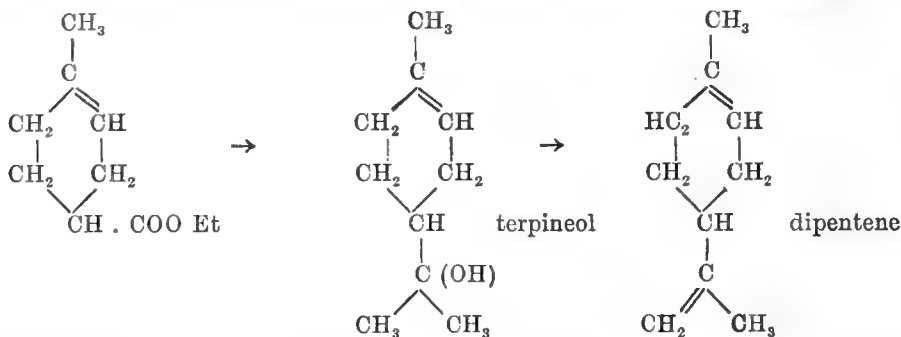


The ester of this acid on subsequent treatment with magnesium-

¹ *Journ. f. Prakt. Chem.*, **55** (1897).

² *Journ. Chem. Soc.*, 1904, p. 654.

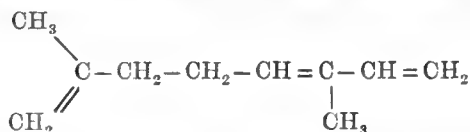
methyl-iodide passes into terpineol, from which, by splitting off the elements of water with potassium bisulphate, dipentene is obtained.



The products thus obtained were shown to be identical with those of natural origin.

In 1902 the examination of the distillation products of caoutchouc was again taken up by Dr. C. D. Harries,¹ then at Berlin, and now Professor of Chemistry at Kiel. Harries assumed that the dipentene was a secondary product of the decomposition of the molecules of the colloid indiarubber, that the primary products were molecules of isoprene, or 'di-isoprene,' and that dipentene was found from these in a secondary reaction. He examined carefully the dipentene fraction of the indiarubber distillate, boiling-point 150°–200°, and found that dipentene was never present in greater proportion than 33 per cent., the remaining portion consisting of other hydrocarbons of the formula $\text{C}_{10}\text{H}_{16}$. Two of these were isolated. One fraction, boiling-point 147°–150° (761 mm.), specific gravity 0.8286 at 20.5, $\eta_D = 1.4692$ and molecular refraction 45.54, contained no dipentene.

He considered it to be a hydrocarbon, probably having the following formula, and for which he again revived the name di-isoprene:—



Harries regarded this as possibly identical with the hydrocarbon myrcene obtained from Bay oil.

Another fraction boiling at 168°–169° was also found to contain no dipentene, no solid tetrabromide being formed. It does not give a nitrosite, and on treatment with bromine is coloured deep violet; sp. gr. 0.8309; $N_D = 1.4685$, mol. ref. 45.54.

This he considered to be a new terpene, and it will be again referred to later.

Emil Fischer and C. Harries² showed that when distillation of rubber is carried out in a vacuum (0.25 mm.) only a very small quantity of isoprene or dipentene is produced, the chief products of the reaction being a mixture of high-boiling hydrocarbons (boiling-point 180°–300°, 0.25 mm.).

The action of concentrated nitric acid on the distillation products of rubber was investigated by R. Ditmar.³ All the fractions boiling below

¹ *Ber.*, 35, 1902, 3260, 3266.

² *Ber.*, 35, 2, 2162–2163, 1902.

³ *Ber.*, 37, 2430, 1904.

300° C. were vigorously acted upon, became brown or red in colour, and resins were produced. The fractions boiling above 300° C. gave a sandy amorphous nitro-compound of the formula $C_{10}H_{12}N_2O_6$, which was identical with the compound this author had previously obtained by the action of nitric acid on rubber itself.¹ This compound will be referred to later.

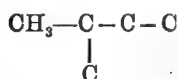
In this account of the various investigations on the distillation products of rubber it has not been thought advisable to explain, in the light of present knowledge, the probable composition of all the fractions isolated by the various investigators. In such a distillate, consisting of so many different substances, none of the fractions obtained are likely to have consisted of quite pure substances; some were certainly complex mixtures. The following table² will give some idea of the compounds isolated which are of seemingly definite composition. The accompanying table also shows the different fractions isolated from time to time:—

Hydrocarbon	Formula	Sp. Gr.	Boiling-point	Constitution	Discoverer
Caoutchene	—	·65 at -2·5	18°12	—	A. Bouchardat
Trimethyl-ethylene	C_5H_{10}	—	33-38	$\begin{matrix} CH_3 \\ | \\ CH_2 \\ | \\ C \\ | \\ CH_3 \end{matrix} \rangle C = CH \cdot OH_3$	Ipatieff and Wittorf
Faradylin	—	·654	33·44	—	A. F. C. Himly
Isoprene	C_5H_8	·6823	37·38	$\begin{matrix} CH_3 \\ | \\ CH_2 \\ | \\ C \\ | \\ CH_3 \end{matrix} \rangle C - OH = CH_2$	O. G. Williams
Myrcene di-isoprene	$C_{10}H_{16}$	·8286	147-150	$\begin{matrix} CH_3 \\ | \\ CH_2 \\ | \\ C \\ | \\ CH_2 \end{matrix} \rangle C \cdot CH_2 \cdot CH_2 \cdot OH = C - OH = CH_2$ <div style="text-align: center;">OH_3</div>	C. Harries
Harries' Terpene (1·5° dimethyl octadiene?)	$C_{10}H_{16}$	·8309	168-169	$\left[\begin{matrix} CH_3 \\ | \\ C - CH_2 - CH_2 - OH \\ || \\ OH - CH_3 \cdot CH_2 \cdot O \cdot CH_3 \end{matrix} \right]$	C. Harries
Caoutchine (Dipentene)	$C_{10}H_{16}$	·8423	(171) (175-6) (180-181)	$\begin{matrix} O \\ || \\ CH_3 \\ | \\ OH \\ | \\ CH_2 \\ | \\ CH \\ | \\ O \\ || \\ CH_3 \end{matrix}$	A. F. C. Himly
Hevéène	$C_{20}H_{32}$ ($C_{15}H_{24}$?)	·921	252	—	A. Bouchardat
Polyterpene	—	—	Above 300	—	O. Wallach

With regard to the theoretical value of the investigations of the pyrogenic decomposition of rubber as affecting our knowledge of the constitution of the rubber molecule, the following conclusions can be drawn:—

(1) The rubber hydrocarbon is closely related to the terpenes, and any formula expressing its constitution must also be explanatory of the easy transition of this hydrocarbon into isoprene and dipentene.

(2) The existence of the complex



¹ *Ber.*, p. 1401, 1902.

² See Ditmar, *Der pyrogene Zerfall des Kautschuks*, 1904.

Name	Date	50°	100°	150°	200°	250°	300°
Barnard, Beale and Enderby	1833 1834	X b. p. 38° sp. gr. '680					
Liebig	1835	35° | sp. gr. '673	65° |				
Gregory	1836	32° | sp. gr.	77° |				
Dalton	1834	X b. p. 42° sp. gr. '68	143° | sp. gr. '837	166° |	High-boiling portion sp. gr. '86		
Himly	1835	33°-44° | sp. gr. '654	Faradayin	171° | X Caoutchine			
Bouchardat . .	1837	X b. p. 18°-12 sp. gr. '65					X b. p. 252° Hevéene
G. Williams . .	1860	X b. p. 37°-38° sp. gr. '68	Isoprene	170°-173° | |			
Wallach	1885	b. p. 34°-39°	Isoprene	X 180°, Cinen c, Dipentene, Caoutchine			
Tilden	1882	X 35°					
Harries	1902		X X 147°-150° sp. gr. '8386 Myrene? Dimethyl octadiene	X X 168°-169° 180°			
Fischer and Harries	1904						(180°-300°) 25 mm.

must be assumed in the rubber molecule, as it occurs in all the examined decomposition products.

(3) Isoprene and dipentene do not occur in the rubber molecule as such, but are produced by the disruption of a larger or more physically complex molecule at a high temperature, for, as Fisher and Harries have shown, if the distillation is conducted at as low a temperature as possible these compounds are not produced in any considerable quantity.

We will now pass on to a consideration of the compounds which have been obtained by the direct action of various reagents on the caoutchouc itself.

Direct Derivatives of Caoutchouc.

Comparatively speaking, very little work had been done until quite recently in the direction of obtaining direct derivatives of indiarubber which could be regarded as definite compounds, or throw any light on the constitution of the molecule.

Vulcanisation Compounds.

In 1839 Goodyear first definitely established the fact that indiarubber on treatment with sulphur at high temperatures became vulcanised; that after such treatment it maintained its elastic properties between wide ranges of temperature. He also discovered ebonite, the final product of the action of sulphur on rubber. Subsequently Hancock discovered the process independently in England, and since that time many investigators have been engaged in work on vulcanisation both with sulphur and with sulphur chloride. For many years, however, no definite compounds were described; nor, in fact, does anything definite with regard to the true nature of the process seem to have been known. In most cases sulphur was simply said to be absorbed.

Burghardt¹ regarded vulcanisation as consisting in the replacement of the hydrogen of the caoutchouc 'resin' by sulphur, but no experimental evidence was brought forward of such being the case. Weber pointed out that the small amount of sulphuretted hydrogen liberated during the process of vulcanisation was not reconcilable with a process of substitution.

In 1894² C. O. Weber prepared from indiarubber, by vulcanisation with sulphur chloride, a yellowish white compound, $C_{10}H_{16}S_2Cl_2$, in the form of friable flakes or of horny granules. This was insoluble in all organic solvents in the cold, but dissolved with decomposition in hot solutions of aromatic hydrocarbons and terpenes. On analysis it gave the following figures:—

	I	II	Calculated for $C_{10}H_{16}S_2Cl_2$
C	43·61	43·51	44·28
H	6·21	6·14	5·90
S	23·88	23·81	23·62
Cl	25·97	26·11	26·19

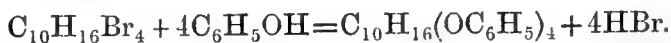
Weber termed the compound polyprene sulpho-chloride. No sulphuretted hydrogen or hydrogen chloride was evolved during the formation,

¹ *Chemistry of Indiarubber* (Weber), 1902, p. 47; Thorpe's *Dict. Appl. Chem.* vol. ii. 312.

² *Ibid.*, p. 97; also *J. S. C. I.*, 1894, p. 11.

derivative, which on analysis was found to be $C_{10}H_{15}Br_5$. The authors suggested that the compound $C_{10}H_{16}Br_6$ was first formed, and that then, by the splitting off of hydrogen bromide, this passed into $C_{10}H_{15}Br_5$. The caoutchouc tetrabromide $C_{10}H_{16}Br_4$ was afterwards prepared and examined by C. O. Weber.¹ He found that it was best obtained by slowly dropping bromide into a well cooled solution of pure rubber in chloroform until slight excess of Br was present, afterwards running the solution in a fine stream into alcohol, which precipitates the bromide in fine white flakes. These were filtered, washed on the filter with alcohol, and dried below $40^\circ C$. At $60^\circ C$ this tetrabromide begins to decompose, HBr is given off, and the colour becomes darker. Caoutchouc tetrabromide is fairly soluble in the cold in chloroform, and in thiophenol, but insoluble in most organic solvents. On heating it is soluble in pyridine and piperidine, but the solution is attended by the loss of HBr.

Boiling alcoholic potash has little effect upon it, but on treating with sodium ethylate in a closed tube the bromine is gradually though not completely removed, and, to some extent, ethoxyl groups are substituted. Oxidising agents, such as nitric and sulphuric acids, affect it very slowly. When treated with phenol, hydrogen bromide was evolved and a substance formed which on analysis gave figures corresponding with those calculated for a tetroxyphenyl-polyprene of the formula $C_{10}H_{16}(OC_6H_5)_4$.



By varying the conditions of the preparation other derivatives were obtained containing more oxygen than is indicated in the above formula; e.g., $C_{10}H_{16}O_2(OC_6H_5)_4$ and $C_{10}H_{16}O_5(OC_6H_5)_5$. On treatment with aqueous or alcoholic soda these bodies split off phenol. Other phenols and naphthols were found to act in a similar manner on the tetrabromide.

Gladstone and Hibbert considered that iodine had very little action upon rubber dissolved in chloroform, but Weber found that on treating such a solution with a large excess of iodine an unstable straw-coloured product was obtained, which gave analytical figures agreeing with the formula $(C_{10}H_{16}I_3)_x$.

Weber also investigated the action of hydrochloric acid upon caoutchouc in chloroform solution. He found that when dry hydrogen chloride gas was used the product was an indefinite sticky substance, but that if the gas were moist a white friable substance was obtained, readily soluble in chloroform, but almost insoluble in most other solvents. Its analysis agreed fairly well with the formula $C_{10}H_{18}Cl_2$. It dissolved in organic bases, but apparently with the loss of HCl.

Hydrobromic acid yields with caoutchouc a very unstable substance, which Weber was unable to obtain in the pure state.

Hydriodic acid.—Berthelot² stated that on treating indiarubber with hydriodic acid at $280^\circ C$. hydrocarbons of the paraffin series, boiling without decomposition above $350^\circ C$., were produced.

Action of Nitric Acid upon Caoutchouc.

F. C. Achard³ found that nitric acid acted on caoutchouc, with the production of a yellow colour and evolution of NO_2 , CO_2 , and HCN,

¹ *Chemistry of Indiarubber*, 1902, p. 31.

² *Bull. Soc. Chim.*, **11**, 33.

³ Gmelin, *Handb. d. Chem.* (1866), **7**, ii. 1763.

leaving oxalic acid and a substance of a fatty nature. The solution of caoutchouc in strong nitric acid gave, on diluting with water, a yellow precipitate which was soluble in alcohol, acids and alkalis and took fire at 100°.

Wm. Roxburgh¹, on treating rubber from *Urceola elastica* with nitric acid obtained a yellow non-elastic mass.

Schwanert² stated that strong nitric acid attacked rubber vigorously, forming at first a yellow body, which was subsequently decomposed into nitrogen, carbonic acid, and a fatty body.

Terry,³ on treating caoutchouc with dilute nitric acid, produced a nitrated body with explosive properties having the composition C 50.50 per cent., H 6.13 per cent., O 37.94 per cent., N 5.43 per cent.

R. Ditmar,⁴ by the action of strong nitric acid upon caoutchouc, obtained a yellow substance the formula of which, $C_{10}H_{12}N_2O_6$, was arrived at by analysis and confirmed by a molecular weight determination. The substance was shown to be a monobasic acid, was soluble in alkalis, and was precipitated from such solution by acids. On heating it began to sinter at 142°–143° C., and at a higher temperature it was decomposed.

This result was confirmed by Harries,⁵ who also examined the product of direct oxidation of Para rubber.

The compound $C_{10}H_{12}N_2O_6$ was further examined by R. Ditmar in 1904,⁶ who showed that it is probably 3 : 6 or 5 : 6 dinitro-hydrocuminic acid. The alkali salts are red amorphous substances, $C_{10}H_{11}O_4N_2M$, and the methyl ester, $C_9H_{11}O_4N_2COOMe$, is a red powder. The acetylanhydride $C_9H_{11}O_4N_2COOAc$, melting-point 72°, is also an orange-red powder.

On heating the dinitro compound at 100° in a sealed tube with stannous chloride and hydrochloric acid, it is reduced to diamino-dihydro *p*-cuminic acid.

Torrey⁷ proposed a quantitative colour test for the estimation of caoutchouc depending on the action of nitric acid followed by the addition of alkali. The chemical reactions involved were not understood, however, and no definite compounds were isolated.

Action of Nitrous Fumes.

By suspending rubber in light petroleum and passing a rapid stream of nitrous fumes (obtained by the action of nitric acid and arsenious oxide) through the liquid, Harries obtained a colloidal mass which changed into a golden yellow amorphous compound.⁸ The compound was soluble in ethyl acetate but insoluble in ether. Analysis and molecular weight determination indicated the formula $C_{40}H_{62}O_{24}N_{10}$. It was soluble in alkalis and was precipitated from solution by acids. In 1902⁹ the same chemist passed dry gaseous nitrous acid (obtained as before) through a benzene solution of Para rubber. A colloidal precipitate separated out which was insoluble in all reagents except pyridine and aniline, which appeared to decompose it. This was termed nitrosite *a*.

When this nitrosite is further treated with nitrous fumes it is changed into a yellow compound (nitrosite *b*) soluble in ethyl alcohol, acetone or alkalis. It reduces Fehling's solution and decomposes at

¹ See Crell, *Ann. d. Chem.*, **2**, 223 (1801).

² *J. S. C. I.*, 1892, p. 971.

⁶ *Monatsch.*, **25**, 464.

⁸ *Ber.*, **34**, 1901, 2991.

⁴ *Ber.*, **35**, 1902, 1401–2.

⁷ *Indiarubber Journal*, 1905, pp. 417–418.

² *Ann.*, **128**, p. 123.

⁵ *Ber.*, **35**, 3256.

⁹ *Ber.*, **35**, 3256.

130° C. Its molecular weight was found by Raoult's method to be about 600 and its formula $C_{20}H_{30}N_6O_{16}$. On oxidation of this nitrosite with nitric acid a dark yellow powder having the composition $C_{20}H_{31}N_5O_{14}$ was produced, as well as oxalic acid and an oil containing apparently an aliphatic nitro-acid. When potassium permanganate was used as the oxidising agent, the products consisted of a mixture of fatty acids, principally oxalic and succinic acids.

By passing a rapid current of unwashed nitrous fumes into a solution of rubber in *moist* benzene a yellow compound, $C_{20}H_{30}N_6O_{14}$ (nitrosite *c*) was the result. This decomposes at 160° C., and gives on oxidation similar compounds to those obtained from nitrosite *b*.

In a second paper on this subject¹ Harries stated that if the nitrous acid used was previously dried, by passing it through phosphoric oxide, only nitrosites *a* and *c* were formed, the one described as *b* having been produced by oxidation. He had previously passed his nitrous fumes over $CaCl_2$ to dry them, chlorine and nitrosyl-chloride had been formed and oxidation had occurred.

An interesting observation made by Harries is that myrcene, the $C_{10}H_{16}$ hydrocarbon from Bay oil, on heating to 300° for four hours, is partly converted into dimyrcene, $C_{20}H_{30}$, boiling-point 160° to 300° (13 mm), and by the action of nitrous fumes on this compound a nitrosite, $C_{20}H_{30}N_6O_{14}$, is produced apparently identical with nitrosite *c* obtained from rubber.

These results seemed to confirm the opinion that rubber was an unsaturated open-chain hydrocarbon.

Action of Nitrogen Dioxide.

In 1902² Weber found that on passing dry nitrogen dioxide gas, obtained by heating lead nitrate, into a solution of Para caoutchouc in benzene, a coherent amorphous mass separated out, which, on the removal of benzene and washing with alcohol, was obtained as a dark yellow powder. The product was further purified by dissolving in acetone and afterwards precipitating with water. A straw-coloured powder was the result, which on analysis gave figures corresponding to the formula $C_{10}H_{16}N_2O_4$. Subsequent investigators,³ however, were unable to isolate a compound of this composition; the substances generally obtained more nearly approximated to the formula $C_{10}H_{15}N_3O_7$. A compound having this composition and possessing similar properties to Weber's compound has been prepared by Harries by another method and named nitrosite *c*.

Weber proposed the preparation of the 'dinitro caoutchouc' as a quantitative method for the estimation of pure caoutchouc in commercial samples and manufactured articles.

Action of Ozone.

The study of the effect of the treatment of rubber with ozone has, in the hands of Prof. C. D. Harries, not only provided us with a new and interesting class of indiarubber derivatives, but has also contributed

¹ *Ber.*, 35 (1902), 44, 29.

² *Ber.*, 35, 1947.

³ Harries, *Ber.*, 1905, 87-90, and Alexander, *Ber.*, 38 (1905), 181-84.

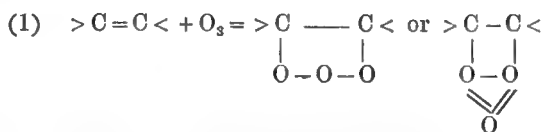
more to our knowledge of the constitution of the caoutchouc molecule than any other previous investigation.

Harries,¹ as a result of his studies on autoxidation, was led to examine the effect of ozone upon unsaturated compounds. He found that on passing ozone through compounds or solutions of compounds of the type of mesityl oxide, highly explosive bodies were formed, which he considered to be of the nature of peroxides, the oxygen adding on at the double bond.

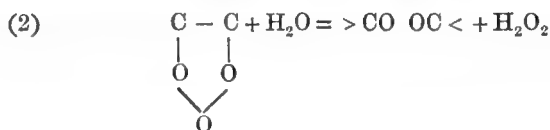


The effect of water on these compounds was to produce a splitting up at the point where the double linkage had been, giving aldehydes and ketones. Afterwards,² from analysis of some of the explosive compounds, he proved that the bodies were not peroxides, but that three atoms of oxygen (one molecule ozone) were added on at the double bond, and he gave the name 'ozonides' to this class of substances.

The action of ozone on unsaturated compounds can be formulated as follows:—



and the action of water in decomposing these bodies is represented:—



hydrogen peroxide being detected in large quantities in the resulting liquids.

In 1904³ pure Para rubber dissolved in chloroform was submitted to the action of ozone. On distilling off the chloroform a colourless syrup remained, which on drying in a vacuum solidified to a glass and possessed all the properties of the ozonides. After purification it was dried in a vacuum, and analysis showed it to have the empirical formula $C_{10}H_{16}O_6$, indicating the addition of two molecules of ozone to the $C_{10}H_{16}$ group. On decomposition of the ozonide with water hydrogen peroxide was formed, and the liquid obtained gave the characteristic reactions of a ketone or aldehyde.

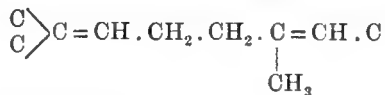
By heating the ozonide for a long time with water, however, complete solution of the products took place and the hydrogen peroxide reaction disappeared. From the residual liquid levulinic acid was obtained and an acid melting at 195° , probably a succinic acid. The acid thus produced was obviously the oxidation product of levulinic aldehyde, and enabled Harries to locate the double linkages in the $C_{10}H_{16}$ molecule.

¹ *Ber.*, **36** (1903), 1923.

² *Ber.*, **37** (1904), 839.

³ *Ber.*, **37**, 2708.

He proposed the following structure as indicating the arrangement of the carbon atoms :—

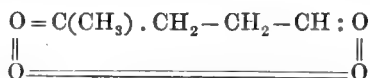


which would give on oxidation

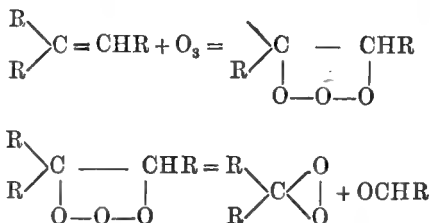


i.e., *levulinic aldehyde*.

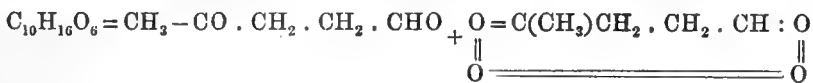
In a subsequent paper¹ Harries explained that the substance melting at 195° was not an acid, as at first supposed, but a peroxide of levulinic aldehyde having the formula—



Its formation was due to a method of splitting up of the ozonides, not previously described :—



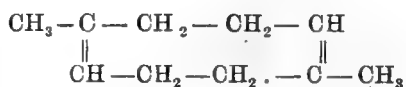
Thus the caoutchouc ozonide is decomposed by water as follows :—



in about equal portions. The peroxide decomposes on long boiling with water into levulinic aldehyde and H_2O_2 , giving subsequently levulinic acid.

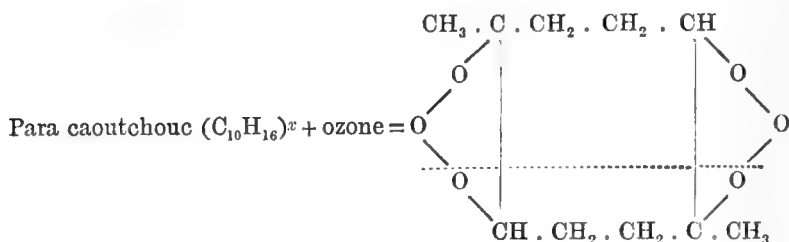
These were the only products of the decomposition, and Harries pointed out that as levulinic aldehyde is the only product formed in the splitting up of the ozonide, the caoutchouc molecule must be formed of a carbon ring, and not an open chain. The molecular weight of the ozonide was found to agree with the formula $\text{C}_{10}\text{H}_{16}\text{O}_6$.

The chemically reacting molecule of the hydrocarbon itself must be looked upon as a derivative of an eight-carbon-ringed body, i.e., 1 : 5 dimethyl-cyclo-octadiene :—

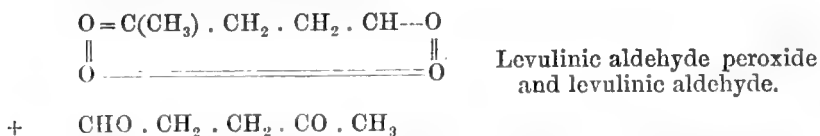


¹ Ber., 38 (1905), 1195.

The ozonide formation would then be represented :—

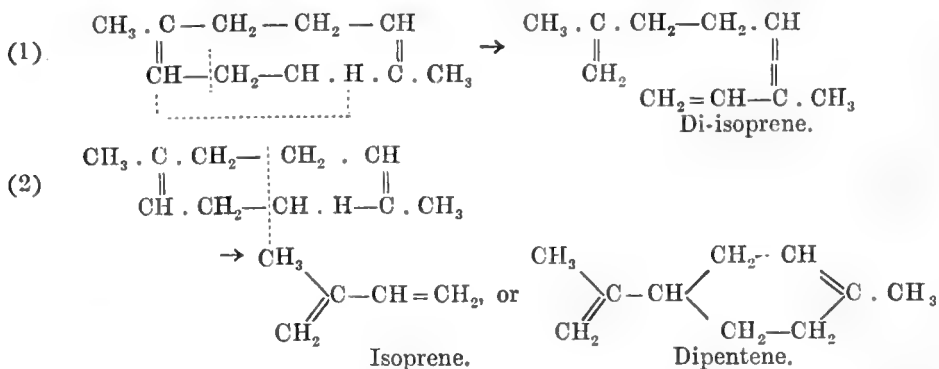


Splitting up as indicated by the dotted line this would give

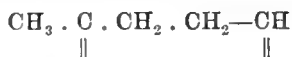


Para rubber must be still expressed $(C_{10}H_{16})_x$, and the size of this physical molecule remains to be determined, though the polymerisation must be through very simple, loose additions.

Harries also indicates how a molecule of the above configuration might easily break down into isoprene or become converted into dipentene or di-isoprene, the known products of the distillation of rubber :—



Professor Harries concludes that caoutchouc is a multiple of C_5H_8 , not, however, of isoprene, but of a similar hydrocarbon with a straight chain, pentadiene :—



This he considers to be probably produced in the plant from the sugars (principally pentoses), and that in the nascent state the above complexes condense, ultimately forming the complex $(C_{10}H_{16})_x$.

In support of this hypothesis he instances the formation of the furans from sugar (Fischer and Laycock), and the fact that α -methyl furan is obtained from beechwood tar (Harries), probably by decomposition of the celluloses. The α methyl furan can easily be split up into levulinic aldehyde, and the connection of this with the above C_5H_8 complex is obvious.

According to the 1 : 5 dimethyl-cyclo-octadiene formula for the chemical molecule of Para rubber, the $C_{10}H_{16}$ complex contains two

double bonds. This is in agreement with our knowledge of the halogen addition compounds of caoutchouc. The view that caoutchouc contains three double bonds is not in the least confirmed. The above formula also agrees with the observed fact that rubber is optically inactive; no asymmetric carbon atom is present in the formula.

Returning to the question of the fraction of the distillation products obtained by Harries (p. 246), it was now found that on treating the fraction boiling 160° – 170° , which at the time he considered to be a new hydrocarbon, with ozone, a glassy mass was obtained, having properties similar to those of the ozonide of caoutchouc, and which gave levulinic aldehyde on boiling with water. It would therefore appear probable that a liquid consisting of unpolymerised molecules of dimethyl octadiene was contained in this fraction.

Oxidation of Indiarubber in Air.

J. Spiller¹ investigated the effect of atmospheric oxygen on a thin film of indiarubber. After exposure of the sample an oxygen-containing product was isolated; this was soluble in alcohol and chloroform, melted below 100° , and possessed the following composition: Carbon, 64.0 per cent.; hydrogen, 8.46 per cent.; oxygen, 27.54 per cent.

Weber (1902) pointed out that these figures agree approximately with the formula $C_{30}H_{48}O_{10}$, or $(C_{10}H_{16})_3 + 5O_2$, and considered that it was an additive product.

W. A. Miller,² in an account of his experiments on the decay of guttapercha and caoutchouc, describes a soft viscous resin produced by the action of air and light on caoutchouc after an exposure of nine months. It was soluble in alcohol, and on analysis was shown to have the composition: Carbon, 67.23 per cent.; hydrogen, 9.54 per cent.; oxygen, 23.23 per cent.

Edgar Herbst,³ by passing a current of purified air for 140 hours through a hot solution of Para caoutchouc in benzene, obtained two substances: (1) a transparent reddish-brown syrup, soluble in light petroleum, having the composition $C_{10}H_{16}O$; and (2) an amorphous, friable, yellow solid of the composition $C_{10}H_{16}O_3$. The latter is sparingly soluble in a mixture of light petroleum and benzene, and separates from this solvent as a hard glassy mass with substantially different properties.

The Study of Hydro-aromatic Substances.—*Report of the Committee, consisting of Dr. E. DIVERS (Chairman), Professor A. W. CROSSLEY (Secretary), Professor W. H. PERKIN, Dr. M. O. FORSTER, and Dr. H. R. LE SUEUR.*

1. *The supposed Identity of Dihydrolaurolene and Dihydroisolaurolene with 1:1-dimethylhexahydrobenzene.*—In the last Report⁴ brief allusion was made to the preparation of 1:1-dimethylhexahydrobenzene,⁵ and it was stated that the main object in view when preparing this hydrocarbon

¹ *Journ. Forts der Chem.* (1865), 575.

² *J. C. S.*, 1865, 273.

³ *Ber.*, 1906, 39, 523–5.

⁴ Reports, 1905, p. 153.

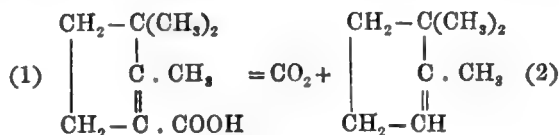
⁵ Crossley and Renouf, *J. C. S.*, 1905, 87, 1487.

was a comparison of its properties with those of dihydrolaurolene and dihydroisolurolene, with which hydrocarbons it has been supposed by Zelinsky and Lepeschkin¹ to be identical. This comparison has now been completed,² with results which prove conclusively that neither dihydrolaurolene nor dihydroisolurolene is identical with 1 : 1-dimethylhexahydrobenzene, as will be seen from the following tabulated summary of their properties :—

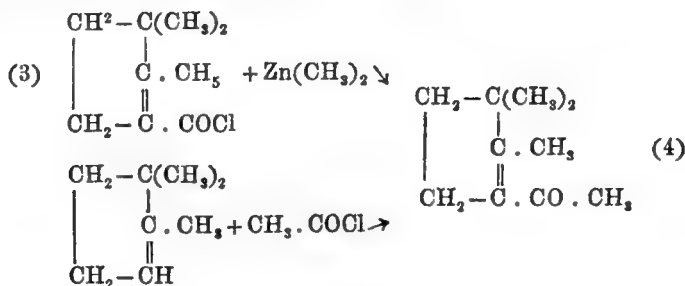
—	B.P.	Sp. Gr.	Odour	Oxidation Product
1 : 1-Dimethylhexahydrobenzene	120°	0.7864	Resembling geranium	$\beta\beta$ -dimethyl-adipic acid
Dihydrolaurolene	111.5–114°	0.7633	Camphoraceous	Oxalic acid
Dihydroisolurolene	113–113.5°	0.7762	Sweet camphoraceous	$\alpha\alpha$ -dimethyl-glutaric acid

There is little to be said regarding the constitution of dihydrolaurolene on the present occasion, but it seems most probable that this substance is a mixture of hydrocarbons ; whereas dihydroisolurolene is proved by the following considerations to be a pentamethylene derivative.

In 1898 Blanc³ definitely established the constitution of isolurolene in the following manner. Accepting his formula for isolurolonic acid (1) as correct, he believed isolurolene to be represented by formula 2.



That is to say, that during the loss of carbon dioxide no change in the structure of the ring takes place. This was proved by the fact that isolurolonic chloride (3), when treated with zinc methide, gave rise to the same ketone (4) as is produced by the action of acetyl chloride on isolurolene in presence of aluminium chloride :



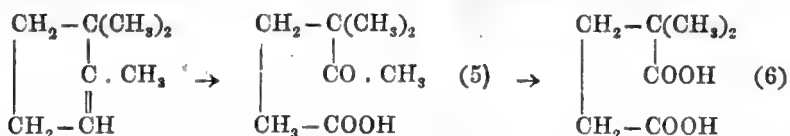
Blanc further showed that when isolurolene was oxidised with potassium permanganate there was obtained γ -acetyldimethylbutyric acid

¹ *Annalen*, 1901, 319, 303.

² Crossley and Renouf, *J. C. S.*, 1906, 82, 26

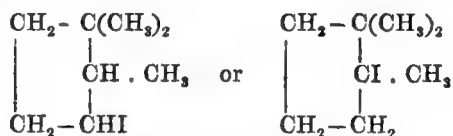
³ *Bull. Soc. Chim.*, 1898 [iii], 19, 699.

(5), previously obtained by him from the oxidation of isolaurolic acid,¹

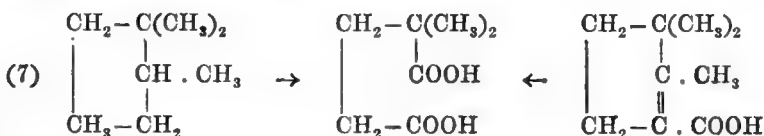


and this ketonic acid, on further oxidation, gave *aa*-dimethylglutaric acid (6). As Blanc says, the formation of γ -acetyldimethylbutyric acid by the oxidation of isolaurolene shows that it can only have the constitution represented by formula 2 and no other. Yet Zelinsky and Lepeschkin, in 1901, did not accept this conclusion, but regarded isolaurolene as a six-ring compound.

Accepting then formula 2 for isolaurolene, the next step was to prove that when isolaurolene was treated with fuming hydriodic acid at a temperature of 120° to 125° no change in the nature of the ring was produced. For this purpose the hydriodide was treated with diethylaniline, when it readily lost the elements of hydrogen iodide, giving an unsaturated hydrocarbon C_8H_{14} , boiling at 108°–108·5°, and possessing properties identical with those of isolaurolene. In order that there should be no doubt on this point, the hydrocarbon was oxidised with potassium permanganate, when it yielded γ -acetyldimethylbutyric acid, and this, on further oxidation with sodium hypobromite, gave *aa*-dimethylglutaric acid. These are the same products as Blanc obtained by the oxidation of isolaurolene (*see above*), and conclusively prove that no isomeric change takes place during the production of the hydriodide, which must therefore have one of the following formulæ:—



There is, moreover, no reason to suppose that heating this hydriodide with zinc dust in aqueous alcoholic solution would produce a change in the construction of the ring, and this is proved by the fact that when the resulting hydrocarbon (dihydroisolaurolene) is oxidised with diluted nitric acid it gives rise to *aa*-dimethylglutaric acid:—



that is, to the same oxidation product as isolaurolic acid yields when treated with diluted nitric acid.²

These experiments prove conclusively that dihydroisolaurolene is a pentamethylene derivative, and is 1 : 1 : 2-trimethylcyclopentane (7), a deduction which receives striking confirmation from the magnetic rotation of dihydroisolaurolene, which has been determined by Dr. W. H. Perkin, Sen.

¹ *Bull. Soc. Chim.*, 1898 (iii), 19, 533.

² *Ibid.*, 1898 (iii), 19, 284.

2. *The Action of Phosphorus Pentachloride on Trimethyldihydroresorcin.*—In the nature of the substances produced, this reaction¹ resembles closely that of phosphorus pentachloride on dimethyldihydroresorcin,² for two bodies are obtained, one hydro-aromatic, namely 3 : 5-dichloro-1 : 1 : 2-trimethyldihydrobenzene (8), and the other aromatic, namely 3 : 5-dichloro-1 : 2 : 6-trimethylbenzene (9).



But whereas, in the case of dimethyldihydroresorcin about 75 per cent. of the theoretical yield of the hydro-aromatic dichloride is formed and only a very small proportion of the aromatic substance, with trimethyldihydroresorcin the result is reversed, the principal product being dichlorotrimethylbenzene.

Dichlorotrimethyldihydrobenzene can be converted into dichlorotrimethylbenzene under the influence of phosphorus pentachloride or bromine, and it has been ascertained that during this conversion the wandering methyl group passes into an ortho position, as has already been observed with several derivatives of dimethyldihydroresorcin.³ This has been proved by analogy, and by a study of the properties of the aromatic dichloride and of the possibility of directly esterifying the dichlorobenzenetricarboxylic acid (dichlorohemimellitic acid) obtained by oxidising dichlorotrimethylbenzene with nitric acid in sealed tubes.

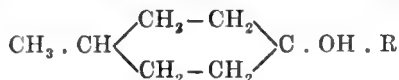
Recent Work on Hydro-aromatic Substances.

By Professor A. W. CROSSLEY.

Hydrocarbons.—In a paper entitled ‘Derivatives of Cyclohexene’ Brunel⁴ gives a *résumé* of work already published, together with a description of certain new derivatives.

1 : 2-, 1 : 3-, and 1 : 4-dimethyltetrahydrobenzenes⁵ have been obtained by the action of zinc chloride on the hydroxydimethylhexahydrobenzenes mentioned below. They give the corresponding hexahydrobenzenes when treated with hydrogen in presence of reduced nickel.

Alcohols.—4-keto-1-methylhexahydrobenzene reacts energetically with organomagnesium compounds⁶ to form tertiary alcohols of the general formula



Alcohols in which R = CH₃, C₂H₅, C₃H₇, C₅H₁₁, C₈H₁₇, C₆H₅, and C₆H₅.CH₂ are described, and also the substituted tetrahydrobenzenes obtained from them, generally by the dehydrating influence of zinc chloride. An exception was noted in the case of magnesium isobutyl bromide, which gives rise almost exclusively to butylene and hydroxymethylhexahydrobenzene.

4-hydroxy-1 : 2-dimethylhexahydrobenzene, 4-hydroxy-1 : 3-dimethylhexahydrobenzene, and 2-hydroxy-1 : 4-dimethylhexahydrobenzene have

¹ Crossley and Hills, *J. C. S.*, 1906, 89.

² Crossley and Le Sueur, *J. C. S.*, 1902, 81, 826, 1533.

³ *J. C. S.*, 1902, 81, 1534; 1904, 85, 264.

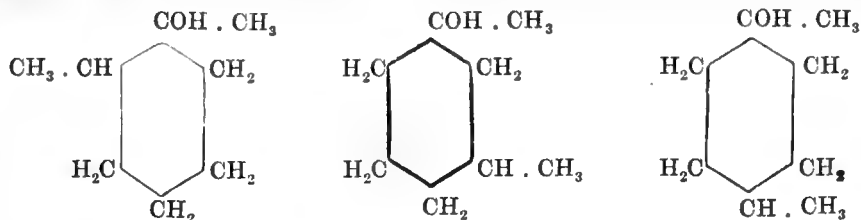
⁴ *Ann. Chim. Phys.*, 1905 [viii], 6, 200.

⁵ Sabatier and Mailhe, *Compt. Rend.*, 1905, 141, 20.

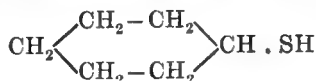
⁶ *Ibid.*, 1906, 142, 438.

been synthesised¹ by passing the corresponding xylene with excess of hydrogen over reduced nickel heated to 190° to 200°. In the cases of the xylenols with the methyl groups in the 1 : 2- and 1 : 3- positions, large amounts of the corresponding xylenes are formed, whereas with the 1 : 4- compound the formation of xylene was not observed, and the hydration mixture consisted of 90 per cent. of the desired alcohol and 10 per cent. of the corresponding ketone.

In the last Report² the hydrogenation of the three cresols was referred to.³ Sabatier and Mailhe have now shown that by treating the ketones obtained in this manner with magnesium methyl iodide, good yields of the three following hydroxydimethylhexahydrobenzenes are obtained⁴ :—



Cyclohexylmercaptan has been described by Borsche and Lange⁵ as a highly refractive liquid of mercaptan-like odour, formed when the sulphon-



chloride, obtained by the action of phosphorus pentachloride on potassium hexahydrobenzenesulphonic acid, is reduced with zinc and hydrochloric acid.

Cyclohexylxanthate,⁵ $\text{C}_6\text{H}_{11}\cdot\text{S}\cdot\text{CS}\cdot\text{OC}_2\text{H}_5$, is formed by the interaction of potassium xanthate and cyclohexylbromide, and is converted by ammonia into cyclohexylmercaptan and xanthamide.

Amines.—Sabatier and Senderens⁶ have shown that by the hydrogenation of benzonitrile in presence of nickel at 200°, ammonia and toluene are almost exclusively formed. Frebault⁷ now proves that under modified conditions the reduction takes place similarly to that of the aliphatic nitriles, and that primary and secondary aromatic amines can be thus obtained. Benzonitrile gives rise to benzylamine and dibenzylamine in approximately equal amounts, and *p*-tolunitrile to *p*-methylbenzylamine and di-*p*-methylbenzylamine.

Ketones.—As a further instance of the use of Grignard's reaction the preparation of cyclohexylacetone may be quoted. Though this substance is not obtainable by the interaction of chlorohexahydrobenzene and ethyl sodioacetoacetate, it may be produced by the action of hexahydrobenzylmagnesium iodide on acetaldehyde.⁸

Dihydroresorcins.—Ethyl malonate combines with cinnamylideneacetone⁹ to give cinnamylidenedihydroresorcin (10), which on oxidation with potassium permanganate is converted into benzoic and tricarballic

¹ *Compt. Rend.*, 1906, **142**, 553.

² Reports, 1905, p. 155.

³ *Compt. Rend.*, 1905, **140**, 350.

⁴ *Ibid.*, 1905, **141**, 20.

⁵ *Ber.*, 1906, **39**, 392.

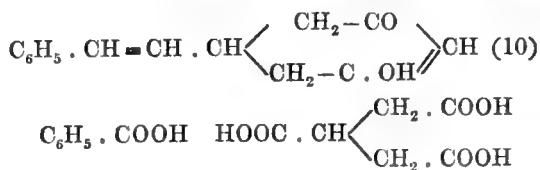
⁶ *Compt. Rend.*, 1905, **140**, 482.

⁷ *Ibid.*, 1905, **140**, 1036.

⁸ Freundler, *Compt. Rend.*, 1906, **142**, 343.

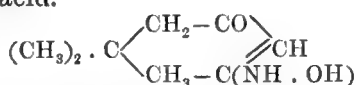
⁹ Vorlaender and Groebel, *Annalen*, 1906, **345**, 206.

acids ; hence the addition of the elements of ethyl malonate must have

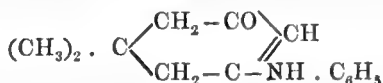


taken place at the $\alpha\beta$ position relative to the carbonyl group. As this addition may be influenced by the tendency to form a six-ring, cinnamylacrylic acid, $\text{C}_6\text{H}_5 \cdot \text{CH} : \text{CH} \cdot \text{CH} : \text{CH} \cdot \text{COOC}_2\text{H}_5$, where no ring formation is possible, was substituted for cinnamylideneacetone, but again addition took place at the $\alpha\beta$ position.

Dimethyldihydroresorcin (and also probably phenyldihydroresorcin) gives rise to a crystalline and an amorphous oxime.¹ The former can be converted into a dioxime, whereas the latter cannot, nor does it give an acetyl derivative, which makes it appear probable that it has the constitution of a hydroxamic acid.

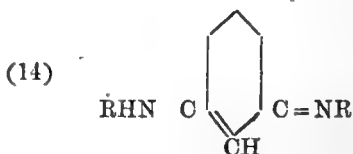
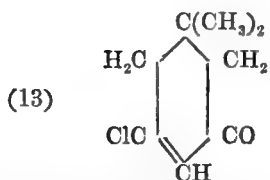
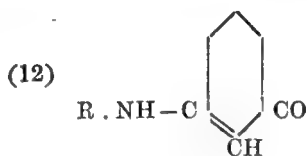
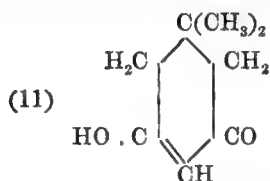


On the other hand, both oximes have faintly acid properties, and may therefore be stereoisomerides. Dimethyldihydroresorcin gives a mono-phenylhydrazone and also a mono-anilide, which behaves in a similar



manner to the amorphous oxime, in not condensing with a second molecule of aniline to form a di-anilide, nor does it yield an oxime, but it gives an acetyl derivative. The compounds formed by the condensation of dimethyldihydroresorcin with *o*- and *p*-toluidine and α -naphthylamine are also described.

Work of a similar nature, but more comprehensive, has been carried out by Haas,² who shows that dimethyldihydroresorcin (11) condenses with only one molecule of a primary base (ammonia, aniline or *p*-toluidine), water being eliminated between the hydroxyl group of the dihydroresorcin and a hydrogen atom of the amino group, to give a compound of the type of formula 12. On the other hand, chloroketodimethyltetrahydrobenzene (13) reacts directly with two molecules of a primary base, yielding a compound of the type of formula 14.

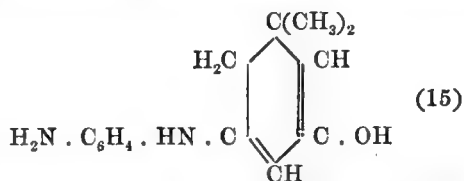


¹ Gittel, *Cent. Blatt*, 1896 (1), 33.

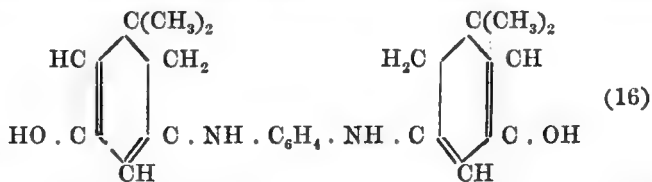
² *J. C. S.*, 1906, 89, 187.

Neither dimethyldihydroresorcin nor chloroketodimethyltetrahydrobenzene reacts with secondary amines. The replacement of the hydroxyl group in dimethyldihydroresorcin by a basic group such as NH_2 -, $\text{C}_6\text{H}_5\text{-NH-}$, or $\text{C}_7\text{H}_7\text{-NH-}$, causes the remaining ketonic oxygen atom of the dihydroresorcin to become hydroxylic, as shown by the colour reactions of the resulting substances with ferric chloride and their behaviour towards phosphorus trichloride. If, however, the substituting group is rendered more acidic by the introduction of an acetyl group, this second oxygen atom becomes ketonic and is able to condense with semicarbazide. The mono-derivatives produced from dimethyldihydroresorcin can be converted into the di-derivatives directly obtainable from chloroketodimethyltetrahydrobenzene either by condensation with a second molecule of the primary base in presence of zinc chloride, or by the action of the phosphorus haloids.

In a second communication¹ it is shown that molecular proportions of dimethyldihydroresorcin and a primary diamine (*m*- or *p*-phenylenediamine) interact to give an 80 per cent. yield of the simple condensation product (15), but, in addition, there is also formed a small amount of the

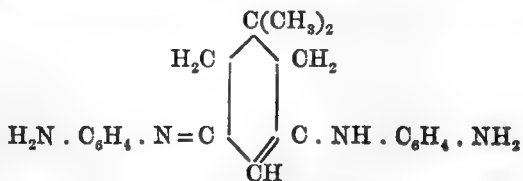


compound (16) resulting from the condensation of two molecules of the



dihydroresorcin with one of the diamine. The compounds of formula 15 function as di-acid bases, giving rise to dihydrochlorides, which react with one molecular proportion of platinum chloride to form platinum salts; they are insoluble in water, but dissolve in alcohol to form neutral solutions which produce with ferric chloride a reddish-brown coloration; with acetic anhydride they yield mono-acetyl derivatives only, which still give a colour reaction with ferric chloride. The di-substituted phenylenediamines (16) are also di-acid bases having a neutral reaction; they are not acetylated by boiling with acetic anhydride, and may be recrystallised without change from glacial acetic acid; in alcoholic solution they give with ferric chloride a reddish-yellow colour.

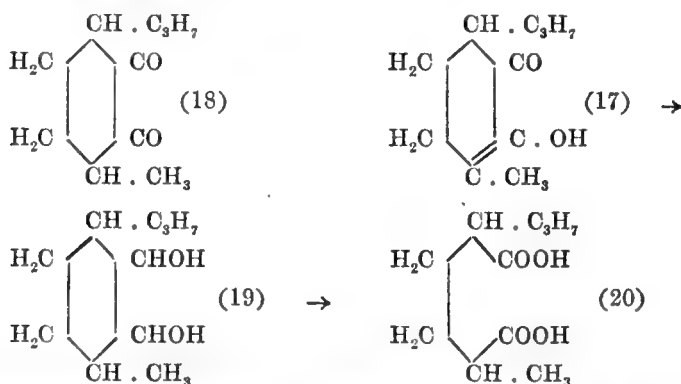
Chloroketodimethyltetrahydrobenzene condenses at once with two molecules of *m*-phenylenediamine to give the hydrochloride of a base having formula



¹ *J. C. S.*, 1906, 89, 388.

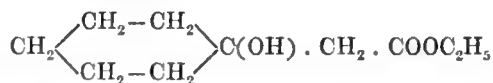
During the investigation of the above-mentioned substances it has been shown¹ that the numbers obtained for the percentage of nitrogen were from 2 per cent. to 5 per cent. too high for the calculated values. This discrepancy has been proved to be due to the presence of marsh gas, and a method for obviating the difficulty has been devised.

A further investigation of buccocamphor (diosphenol)² has shown it to possess a constitution closely resembling the dihydroresorcins. It has the molecular formula $C_{10}H_{16}O_2$, and is a ketone alcohol (17) or diketone (18) containing a hexamethylene ring, with methyl and isopropyl groups in the 1 : 4 position, and in which the double bond must be attached to the carbon atom carrying the methyl group.

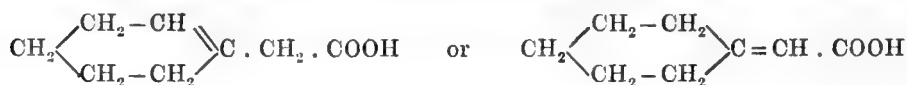


On heating with hydrogen chloride buccocamphor is quantitatively converted into thymol, and on reduction with sodium in alcoholic solution it yields a glycol (19), which on oxidation is converted into α -methyl- α' -isopropyladipic acid (20), thus definitely establishing its constitution. The authors have succeeded in synthesising buccocamphor by treating hydroxymethylenementhone with ozone

Acids.—Keto-hexahydrobenzene condenses with ethyl bromoacetate under the influence of magnesium³ to give ethyl cyclohexanolacetate :—

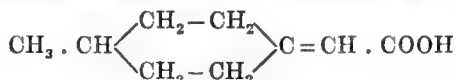


By loss of water and subsequent hydrolysis cyclohexeneacetic acid is



obtained, which, when oxidised with potassium permanganate, gives a non-aldehydic compound containing seven carbon atoms.

Marckwald and Meth⁴ have described an acid believed by them to be 1-methylcyclohexylideneacetic acid. It melts at 41°, and has been



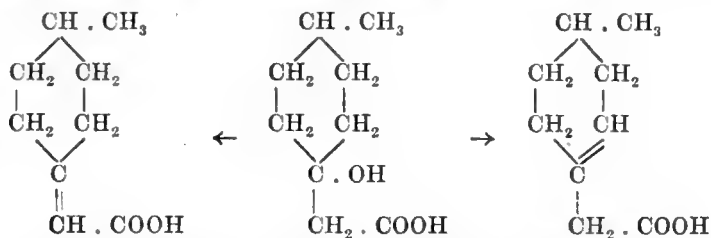
¹ *J. C. S.*, 1906, **89**, 570.

² Semmler and MacKenzie, *Ber.*, 1906, **39**, 1158.

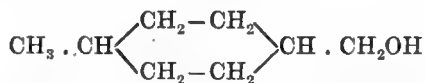
³ Wallach, *Annalen*, 1905, **343**, 40.

⁴ *Ber.*, 1906, **39**, 1171.

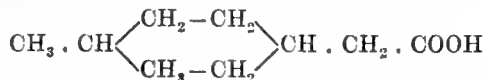
resolved into active modifications by fractional crystallisation of the cinchonine salts. It was obtained by the removal of the elements of water from methylcyclohexanolacetic acid, which, as pointed out by Perkin and Pope,¹ may take place in one of two ways:—



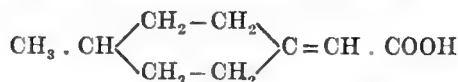
These latter authors have been engaged in an attempt to prepare a substance which, while not containing an asymmetric carbon atom, is yet capable of existing in optically active modifications, and one of the substances selected for examination was methylcyclohexylideneacetic acid. This was prepared from ethyl hexahydro-*p*-toluate as starting point, and which on reduction with sodium and alcohol gives hexahydro-*p*-tolylcarbinol



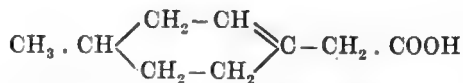
This carbinol is readily converted into hexahydro-*p*-tolyl bromide, which, when heated with potassium cyanide and the product hydrolysed, yields hexahydro-*p*-tolylacetic acid



Bromine acts on the corresponding acid chloride with formation of α -bromohexahydro-*p*-tolylacetic acid, and the ester of this bromo-acid is decomposed by boiling with diethylaniline into hydrogen bromide and ethyl methylcyclohexylideneacetate. On hydrolysis the free acid is obtained melting at 70°–71°, and the method of preparation leaves no doubt that its constitution is represented by the formula



The acid described by Marckwald and Meth is possibly the isomeric acid



Chloro- or iodo-hexahydrobenzene reacts with ethyl sodiocyanacetate or ethyl sodiomalonate in xylene solution, and from either of the resulting condensation products cyclohexylacetic acid may be obtained on hydrolysis.²

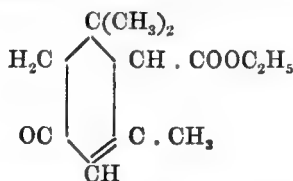
Ethyl isophoroncarboxylate³ obtained by the condensation of ethyl

¹ *Proc. C.S.*, 1906, 22, 107.

² Freundler and Damond, *Compt. Rend.*, 1905, 141, 593.

³ *D. R. P.*, 148080.

isopropylideneacetoacetate and ethyl sodioacetoacetate, is a δ -ketonic ester with the following constitution¹ :—



By reduction with sodium and alcohol, a mixture of stereoisomeric hydroxy acids is produced, which does not consist of one cis- and one trans-acid, as stated in the patent, but of three pairs of cis-trans-isomeric acids, in all therefore of six acids, all of which have been isolated. By heating alone or with dehydrating agents three different stable crystalline lactones were obtained, showing that in the parent ketonic acid the carboxyl and carbonyl groups occupy a para-position relatively to one another. A further proof of this is afforded by the fact that the lactones are oxidised by Beckmann's solution to three stereoisomeric dihydroisophorocarboxylic acids, which distil without decomposition in vacuo, and do not lose carbon dioxide on heating to 200° in air.

Abati and Bernardinis² have isolated two new hydrophthalic anhydrides by the reduction of sodium phthalate with sodium amalgam. Cis- Δ^3 -tetrahydrophthalic anhydride crystallises in white scales, and on heating to 220° to 230° is transformed into Δ^1 -tetrahydrophthalic anhydride.

$\Delta^{1:3}$ -dihydrophthalic anhydride melts at 58°, and on heating to 225° is transformed into another anhydride, which could not be identified.

The trans-hexahydroisophthalic acid, previously described³ as melting at 120° to 122°, has been proved by Perkin and Goodwin⁴ to be a mixture of the cis- and trans-acids, which can be separated by dissolving in a considerable excess of ammonia and heating for some hours with calcium chloride, when a quantity of the calcium salt of the cis-acid is obtained. After repeating this process several times, the mother liquor yielded pure trans-hexahydroisophthalic acid melting at 148°. When the pure trans-acid is treated with phosphorus pentachloride and then bromine, 1:3-dibromo-trans-hexahydroisophthalic acid is produced, which on treatment with methyl alcoholic potash gives a dihydroisophthalic acid, whose constitution is probably represented by the formula



It is isomeric with the acid previously obtained from 3:4-dibromohexahydroisophthalic acid by similar treatment.

Chlorohexahydrobenzene readily forms a Grignard compound with magnesium,⁵ which when acted on with dry sulphur dioxide yields magnesium hexahydrobenzenesulphinate. This latter substance on oxida-

¹ Merling, *Ber.*, 1905, **38**, 979.

³ *J. C. S.*, 1891, **59**, 808.

² *J. C. S.*, *Abst.*, 1905 (1), 599.

⁴ *Ibid.*, 1905, **87**, 841.

⁵ Borsche and Lange, *Ber.*, 1905, **38**, 2766.

tion with potassium permanganate gives a mixture of dicyclohexane-sulphone and the potassium salt of hexahydrobenzenesulphonic acid. The free acid crystallises from alcohol, melts at 90° to 92°, and gives a corresponding acid chloride anilide and ethyl ester.

The Hydrolysis of Sugars. By ROBERT J. CALDWELL, B.Sc.

[Ordered by the General Committee to be printed *in extenso*.]

A.—*Introductory and Historical.*

THE hydrolysis of cane sugar by acids, one of the first chemical changes of which the course was followed, is still a most important subject of study in the field of chemical dynamics. A literature is grown up of some 140 papers, dealing with the change from various points of view; in a large number of cases it is clear the authors have little knowledge of the work which has been published previously. This ignorance has frequently entailed unnecessary reduplication of work, and sometimes it is difficult to reconcile the results of various inquiries. In this report an attempt has been made to bring together all the researches which deal with the hydrolysis of sugar by acids and to discuss the bearing of each paper in its proper place. The moment is an opportune one for such a co-ordination of the literature, in view of the work which is in progress concerning the rate at which hydrolytic change proceeds; secondly, on account of the prominence now given to theories of solution; lastly, because of the bearing which the study of such changes has on the problems of osmotic pressure.

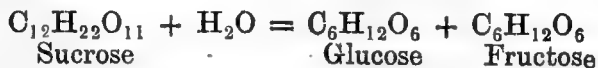
The majority of the researches deal with cane sugar, this being not only an inexpensive pure material but very easily acted upon by acids in comparison with other sugars.

1818. Biot, in his first paper on the optical rotatory power of solutions, showed that cane sugar is dextrorotatory. He followed this up by demonstrating that when cane sugar solutions are boiled they lose not only their crystallising power but their rotatory power is also diminished.

1833. Biot and Persoz studied the conversion of potato starch into dextrin under the influence of dilute sulphuric acid. The optical rotatory power being diminished in this case also, they argued that the change must be taken as an indication of molecular change. Lastly, on

1836. January 11, 1836, Biot announced to the Academy that under the influence of acids, aided if necessary by heating, cane sugar loses its crystallising power and is inverted optically, the sign of the rotatory power changing from right to left.

The inversion of sugar was made the subject of a careful research by Wilhelmy, who showed that the change does not consist in a combination of the acid with the sugar, as after removing the acid by precipitation the sugar still remained 'inverted.' The separation of the product into dextrorotatory glucose and lævorotatory levulose was accomplished later on by Dubrunfaut, who formulated the change by the equation



Wilhelmy showed that the amount of sugar changed in any given

moment is a constant percentage of the amount of unchanged sugar present. In symbols :—

$$\frac{dx}{dt} = k(a - x) \quad \text{where} \quad \begin{cases} a = \text{initial amount of sugar.} \\ x = \text{amount already inverted.} \\ t = \text{time which has elapsed since} \\ \quad \text{the reaction started.} \end{cases}$$

or $\frac{1}{t} \log_e \frac{a}{a-x} = k$

This last expression is the simplest type of mass action equation and is known as *Wilhelmy's Law*. The Law was verified with some
 1874. care by *Fleury*, who pointed out that the inversion is attended
 1862. by an evolution of heat ; also by *Löwenthal* and *Lenssen* and by
 1882-3. *Urech*, who again showed that the amount of sugar hydrolysed
 is proportional to the amount present.

The velocity constant $k = \left(\frac{1}{t} \log_e \frac{a}{a-x} \right)$ in *Wilhelmy's Law* may be taken as representing the rate at which the sugar is inverted.

B.—*Conditions under which Cane Sugar is Inverted.*

B 1.—*Supposed Spontaneous Inversion by Pure Water.*

Maumené imagined that cane sugar could be inverted by water
 1854. alone, as on leaving a solution standing at room-temperature during
 several months invert sugar was formed.

1855. *Béchamp* confirmed this conclusion and showed that zinc and
 calcium chlorides prevented the change. *Béchamp* soon afterwards
 1858. proved, however, that if the solution were kept perfectly sterile no
 inversion occurred. Some antiseptic salts, such as mercuric chloride,
 1864. are said to have an inverting action of their own.

1878. *Pellet's* solutions were probably, like *Maumené's*, not sterile.
 Inversion on *boiling* solutions of cane sugar cannot, however, be
 1872. explained so simply. *Maumené* showed that the inversion of
 sugar on the water-bath is accompanied by the formation of an
 1876. acid. *Lound* claimed that if heated out of contact with the air or
 in contact with air free from carbonic acid, sugar solutions are
 not inverted at all. He attributed *Maumené's* result to the presence of
 carbonic acid.

1883. *Gladstone* and *Tribe* showed that on heating sugar solutions
 the inversion which occurs is accompanied by a darkening of the
 solution and the formation of a volatile substance which gives the
 iodoform test. If, however, a zinc-copper couple be present during the
 boiling no darkening of the solution occurs.

1898. *W. A. Smith* also recorded that the change in optical rotatory
 power of a sugar solution on boiling is due partly to inversion
 and partly to decomposition.

1902. More recently *Kullgren*¹ has pointed out that the hydrogen
 ions² of the water and the invert sugar are not sufficient to
 account for the increase in the inversion velocity at 100° C. as the action
 proceeds. He demonstrated by titration that an acid is gradually formed
 from the invert sugar and that the curve could be interpreted if due
 allowance were made for this formation of acid.

¹ *Zeits. Phys. Chem.*, 41.

² *Vide infra*, Section E.

B 2.—*Inversion by Enzymes.*

Certain organisms which develop very readily in cane sugar solutions are found to invert the sugar. Such for example are *Aspergillus niger*, *Penicillium glaucum* and most yeasts.

It was first noticed by Dubrunfaut that under the influence of yeasts sugar is converted into *sucrose incrustalisable* and Persoz showed that the change is accompanied by optical inversion. Pasteur supposed that the yeast produced succinic acid, which then inverted the sugar in virtue of its acidity. Berthelot, however, showed¹ that succinic acid is not sufficiently active to bring about inversion so quickly as it is accomplished² by yeast; moreover, yeast can invert sugar even in an alkaline solution. He succeeded in extracting the nitrogenous active principle of the yeast by water.

This enzyme, 'invertase' or 'sucrase,' which is capable of inverting cane sugar is not present in all yeasts. For instance, *Saccharomyces octosporus*, which is capable of hydrolysing and fermenting maltose, has no action on cane sugar.³ In fact, there is an enzyme specially adapted to hydrolyse every biose and no other sugar.

A useful summary of this subject is given by Euler.⁴

B 3.—*Inversion by Acids.*

Whereas each biose sugar requires a special enzyme to hydrolyse it, the catalytic action of acids is a general property, all acids hydrolysing all bioses. The rate of the action, however, varies enormously with the nature of the acid and of the sugar (*vide* Sections D and M).

The hydrolysis of cane sugar is most readily effected by sulphuric acid; a gramme molecular solution of this acid has an activity 7.4 per cent. more powerful than that of a molecular solution of hydrochloric acid, and is 270 times as powerful as acetic acid.

1880. Even carbonic acid, as Lippmann has shown, can bring about the inversion of cane sugar, this action being the more rapid if the solution be heated under pressure (*see also* Maumené, 1881, and Pfl and Linne, 1905).

B 4.—*Inversion by Acid Salts.*

The 'acid salts' of dibasic acids are also able to bring about inversion. This was remarked upon by Spohr with reference to the acid sulphates.

1886. Trevor used the sugar-inversion method to estimate the 'degree of ionisation,' *i.e.* the acidity of various acid salts, such as sodium hydrogen succinate. Noyes also applied Trevor's method to determine the degree of ionisation of potassium bitartrate at 100° C.

1892. Magnanini-Modena has applied the inversion of cane sugar as a test for KHSO_4 in wine which has been treated with gypsum.

¹ *Comptes Rendus*, 50, p. 980.

² Gayon (1881) has since shown that the action of succinic acid is inhibited by yeast.

³ *Vide* E. F. Armstrong (1905), *Proc. Roy. Soc.*, B 76, p. 603.

⁴ *Zeits. Physiol. Chem.*, 1905, 45, p. 420. *Comp. The Soluble Ferments* by Reynolds Green.

B 5.—*Inversion by Hydrolysed Salts.*

The salts of feeble bases are, to a certain extent, hydrolysed in solution into free acid and base; the free acid is able to invert cane sugar.

1864. This type of inversion was first noticed by Béchamp in the case of
1878. mercuric chloride and was also observed by Pellet.

1884. E. Fischer inverted sugar by means of phenyl hydrazine acetate,
1892. obtaining finally glucosazone; Bach showed that the hydrochloride
and sulphate of hydrazine can also invert sugar.

1896. Béchamp's observations were extended by Long, who found that
cadmium chloride is particularly active in invertive power.

Quantitative estimations of hydrolytic decomposition by the sugar-inversion method have been made by various workers and will be considered in Section K.

B 6.—*Inversion by Solid Catalytic Agents.*

Speranski showed that a clean glass surface does not alter the rate
1890. of inversion of sugar by acid. If, however, glass wool be present,
a considerable amount of alkali is given up to the solution and
the inversion is slowed.

1896. Ráyman and Šulc observed that inversion occurs when cane-
sugar solutions are in contact with finely divided metals, such as
Pt, Pd, Cu, Ag, Os, Ir, but more especially platinum, at 60, 80, and 100
degrees. At the same time they noticed that the solution became coloured
and acidic, owing to decomposition of the invert sugar. They afterwards

1897. proved that formic and pyrolevulinic acids are produced mainly
from the levulose; in the next year they concluded that the effect

1898. produced by platinum is partly a catalytic oxidation and partly
a direct inverting action, for as soon as the platinum is added to the
solution acidity can be detected.

1904. Plzák and Hušek have carried the proof of this explanation
still further by showing that platinum and palladium have no
invertive power when entirely free from their oxides. A sugar solution
may be boiled for hours with platinum black before hydrolysis sets in.
If, however, the metal be air-dried beforehand, it gets a coating of oxide
and becomes active, the activity depending upon the time of drying.

1904. Lindet, on the other hand, found that certain metals, such as
Cu and Pb, accelerate inversion, whilst others, such as Fe and Cd,
retard it. He supposed that small quantities of hydroxides are formed
from these metals, some of which are acidic and others basic towards cane
sugar. Pt, Ag, Au, &c., are said to have no action. Lindet also argued
that as sugar has a slight conductivity it should be sufficiently acidic to
hydrolyse itself in boiling solution; he explained the non-occurrence of
inversion on boiling in glass vessels to be due to the fact that alkali
derived from the glass neutralises the acidity of the sugar itself. With
regard to the case of platinum, there can be little doubt that the action

1905. is an oxidising one, Vondráček having recently demonstrated that
a specimen of platinum black, once used to effect inversion, loses
its activity towards a second sugar solution unless it be dried in air at
150°. Furthermore if a solution undergoing inversion in presence of
platinum be filtered from the metal, the action continues as a simple

unimolecular change; further proof of the presence of acid can be deduced from the electrical conductivity of a solution so treated.

It is, therefore, not to be credited that platinum or palladium black
1900. can invert cane sugar catalytically. Sulc, indeed, has shown that
palladium has a very unfavourable effect, diminishing the hydro-
lytic activity of hydrochloric acid towards cane sugar, maltose, raffinose
and also methyl acetate.

It is permissible to question the validity of the conclusion arrived at
1906. by Neilson that platinum black can hydrolyse starch, salicin and
amygdalin at 40°.

B 7.—*Hydrolytic Activity of Light.*

Raoult claimed to have established that six months' exposure to light
1871. had brought about the inversion of a sterile solution of cane sugar,
whilst a second sample, kept in the dark, was not inverted. A
trace of acidity in the one specimen would account for the result obtained:
1875. in fact, Kreusler, on repeating the experiment several times with
pure material, failed to obtain any inversion at all.

1883. Gladstone and Tribe also showed that neither light nor air, alone
or in conjunction, can change cane sugar solutions when left for
seventeen months at room-temperature. Raoult's experiment was also
repeated and a negative result obtained.

1886. Duclaux, whilst agreeing that light alone cannot invert cane
sugar, maintains that the velocity of inversion by acids is lower in
absence of light.

1900. Gillot, too, claims to have demonstrated that light, especially
violet light, aids the inversion of sugar by a mineral acid. As no
thermostat was used in his experiments, the small difference observed
may well have arisen as a consequence of the slightly lower temperature
of solutions kept in the dark.

C.—*Methods of Measuring the Velocity of Inversion.*

C 1.—*Polarimeter Method.*

The velocity of inversion was first successfully measured by Wilhelmy
by means of the polarimeter; the majority of subsequent observers have
followed his example. The change in the optical rotation on passing from
cane sugar ($[\alpha]_D = +66^\circ$) to invert sugar ($[\alpha]_D = -28^\circ$) is so large that it
is not difficult to obtain accurate measurements even with a compara-
tively rough polarimeter. The chief error in most of the researches is
probably that arising from fluctuations of temperature.

C 2.—*Titration Method.*

Löwenthal and Lenssen appear to be almost the only investigators
1862. who have used the cumbersome method of titration with Fehling's
Solution.

C 3.—*Volume Method.*

The inversion of sugar, accompanied as it is by the chemical com-
bination of part of the solvent water and by the substitution of two
molecules of monose for one of biose sugar, gives rise to a diminution in

the total volume of the solution. This contraction during inversion was noticed by Graham.

1869. Dubrunfaut measured the rate at which the contraction occurs and hence calculated the rate of inversion. He imagined the change to follow a parabolic law instead of a logarithmic one.

1872. Chancel measured the total amount of contraction when sugar is converted into invert sugar by a trace of sulphuric acid at 100° and proposed to use the method for estimating cane sugar.

1901. More recently Duane, in America, unaware of previous work, has succeeded in obtaining fairly good velocity constants by observations of the volume change of the solution undergoing inversion.

C 4.—*Osmotic Pressure Methods.*

As each molecule of cane sugar is converted into two molecules of monose, the total number of dissolved molecules will increase. Hence the boiling and freezing points of the solution will change.

1894. By determining the boiling-points at intervals Trevor and Kortright were able to calculate the velocity constant with a fair degree of accuracy. The method, however, is of very limited application.

1899. Kahlenburg, Davis and Fowler, on the other hand, made determinations of the freezing-point to measure the inversion velocity in presence of coloured materials, which prevent the use of the polarimeter. Test experiments showed that the same value for the velocity constant was obtained by polarimeter and freezing-point methods.

C 5.—*Refractive Index Method.*

A change in the refractive index of the solution accompanies the inversion of cane sugar.

1901. Duane has made measurements of the velocity with the aid of this property, using a photographic method to determine the index of refraction from time to time.

C 6.—*Conductivity Method.*

Seeing that water molecules are used up during the hydrolysis of cane sugar, the ratio *acid* : *water* must change. Bevan has recently shown that this change is accompanied by a slight decrease in the conductivity of the acid; by measuring the resistance of the solution from time to time, he was able to follow the course of the hydrolysis.

D.—*Influence of the Nature of the Acid employed.*

Biot foresaw that comparative experiments with molecular amounts of divers acids would yield results of great interest but he was unable to follow the subject up.

1862. Löwenthal and Lenssen showed that the velocity of inversion depends entirely on the acids used and were of the opinion that weak acids like acetic acid cannot invert cane sugar at all.

1884. Battut, however, arrived at the astonishing conclusion that acetic, tartaric and sulphuric acids are equally active towards cane sugar.

The importance of the kind of acid used was also emphasised by
 1874. Behr, whilst Fleury attempted to trace a connection between the
 1875. 'activity' of an acid in hydrolysing sugar and its molecular dif-
 fusibility as calculated by Graham.

The first comprehensive attempt to compare the 'strengths' of the
 acids was made by Ostwald. In a much-quoted paper he gave
 1884. a table comparing the 'activity' of acids in inverting sugar
 with their activity in hydrolysing methyl acetate. There is, indeed,
 in the case of twenty acids a very fair agreement between the two sets
 of values.

Later on in the same year Ostwald published a table comparing
 1884. the electrical conductivities of thirty different acids with their
 powers of hydrolysing sugar and methyl acetate. The order of the acids
 as regards their conductivity is the same as their order of activity in
 catalytic actions, although the agreement is not of a quantitative order.
 This paper was written to obtain priority over Arrhenius, who was already
 in this field of inquiry. In the case of weak acids a better proportionality
 obtains between the conductivity and inverting power, so that in order
 1885. to explain the lack of proportionality in the case of strong acids
 Ostwald supposed some disturbing effect to be introduced by the
 acid itself, similar to the known effect of altering the initial concentration
 of the sugar.

Koral supplemented Ostwald's table by comparing invertive
 1887. power and conductivity of benzoic and *p* oxy-benzoic acids.

A similar comparison has been made recently for a series of
 1906. unsaturated aliphatic acids by Fichter and Müller.

Gillot also compared the activities of oxalic, tartaric, and citric
 1899. acids. His paper, however, contains no new result.

According to Arrhenius, the divergence of the invertive activity
 1889. of an acid from its electrical activity is to be attributed to a
 secondary disturbance introduced by the acid—namely, an alteration in
 the amount of 'active sugar' (*vide* Section F). It is a significant fact
 that the 'activity' of an acid seems to depend to a large extent on the
 particular interaction which is used as a criterion; this is well seen in the
 table given in Section M.

An interesting point in this connection is the velocity of inversion
 by a pair of optically antimeric acids, more especially as the enzymes
 which condition inversion are asymmetrical substances. Emil
 1898. Fischer measured the rates of inversion effected at 90° C. by
 dextro- and lævo-camphoric acids; he found them to be indistinguishable.
 He justified his experiment on the grounds that, although the conductivity
 of the two acids is the same and inverting power is known to be pro-
 portional to conductivity, yet possibly the presence of the optically active
 sugar might alter the conductivities of the dextro and lævo acids to a
 different extent and hence also their invertive powers. It is evident
 from this that Fischer was inclined to some such explanation of the
 function of the acid as he has given with such success in the case of
 catalysis by enzymes.

This question was reopened by the author, who has measured
 1904. the inversion of cane sugar by the β sulphonic acids of dextro- and
 lævo-camphor with great care. No difference could be detected between
 the activities of the two acids in this case either, so that Fischer's result is
 confirmed.

1906.

E.—Theories of the Action of Acids in effecting Inversion.

E 1.—The Ionic Theory.

The theory which has dominated the literature of the subject during the last fifteen years is that proposed by Arrhenius as a corollary to his ionic dissociation hypothesis. The ionic hypothesis was first advanced in 1883, in a paper to the Swedish Academy, as an improvement on the Clausius-Williamson dissociation hypothesis. Arrhenius took the electrical conductivity of an acid as a measure of its chemical affinity and gave a table comparing Ostwald's and Thomsen's 'avidity values' with the conductivities of a number of acids. This thesis, although noticed by Ostwald (*see* Section D), did not at the time attract universal attention. For instance, Lodge, in his report on electrolysis to the British Association in 1885, does not mention it. In 'Zeits. Physik. Chem.,' vol. xxii., Arrhenius brought his theory into popular notice by explaining the exceptions to Raoult's cryoscopic laws and Van't Hoff's laws of osmotic pressure of solutions (published in 1886) by means of his dissociation assumptions. The 'activity coefficient,' which Lodge had called the 'dissociation ratio,' viz., the ratio of electrolytically active to the total number of molecules, could be ascertained, hence the 'ionisation' and the freezing-point depression could be calculated. Where the agreement was bad Arrhenius showed that the freezing-point determinations, not the conductivities, were at fault. Although Arrhenius in this paper discussed the various physico-chemical properties of solutions of electrolytes, he made as yet no reference to the inversion of sugar.

In 1889 Arrhenius definitely stated that the hydrolysis of cane sugar is a property of the free hydrogen ions of the acid. There were a large number of facts to be explained away before this theory could be made plausible. He saw that 'a difficulty arises from the fact that the velocity of inversion . . . can under some conditions be increased . . . although the number of acting ions is decreased.' From a consideration of the temperature coefficient of the change, however, Arrhenius postulated his theory of an 'active part' of the cane sugar; this part was arbitrarily assumed to change to meet the requirements of his ionic theory in every case.¹

Trevor accepted Arrhenius's theory *in toto* and used the inversion of sugar as a means of estimating the number of hydrogen ions in solutions of very weakly acid substances. Noyes performed a similar work with the bitartrates.

The principal argument in favour of the above view is the result arrived at by Palmaer and also by W. A. Smith, namely, that in very dilute solutions the rate of inversion is strictly proportional to the number of hydrogen ions. These researches are criticised in Section G 1.

On the other hand, the variation in the activity coefficient of an acid when used to hydrolyse a different sugar (Section M), the effect of adding a neutral salt of the acid (Section J), the influence of high pressures (Section K) and of alcohol (Section H 2), coupled with the evidence brought forward by the author elsewhere, all militate against the acceptance of this hypothesis.

¹ See Section F.

E 2.—Euler's Hyper-ionic Theory of Catalysis.

Euler has postulated the view that there is no ground for distinguish-
 1899. ing between electrolytes and non-electrolytes and regards all sub-
 stances as electrolytes. Cane sugar is supposed by him to be
 slightly ionised in solution and action is said to occur between the ions
 of cane sugar and the ions of water. The acid is supposed to bring
 about catalysis by increasing the total number of ions in the product
 $C_A C_B C_H C_{OH}$, where A and B are the imaginary ions of sugar. It appears
 1900. as if basic substances also should be able to invert sugar on this
 hypothesis! The view was also applied to catalytic oxidation by
 platinum black.¹

1900. The same amazing theory was discussed in 'Berichte' 33 with
 reference to the saponification of ethyl acetate, which Euler explains
 has the character of a neutral salt. He also discussed the accele-
 1900. rating action of neutral salts on the inversion of sugar,² assuming
 the degree of ionisation to be changed in the sense demanded by
 his theory. With regard to the influence of temperature,³ Euler
 1901. explained that Arrhenius's active part (Section F) is in reality the
 proportion of the cane sugar which is dissociated into ions of
 1901. glucose and levulose. Lippmann has sharply criticised Euler's
 theory, maintaining that sugar is a non-electrolyte.

1901. Euler, in his reply to Lippmann, stubbornly maintained that an
 absolute non-electrolyte is not known, although in the case of some,
 as, for instance, cane sugar, the amount of dissociation is very small.

1901. Lippmann, again replying,⁴ pointed out that Loomis⁵ had shown
 by accurate cryoscopic methods that there is not the slightest
 dissociation of the sugars.

Exception to Euler's hypothesis on mathematical grounds was taken
 1902. by Wegscheider,⁶ who came to the conclusion that there is no
 analogy, as supposed by Euler, between ester and salt hydrolysis.
 Hence Euler's theory of catalysis based on this analogy falls to the
 ground.

1902. Euler's reply consisted simply in a reiteration of his theory,
 no new proof being offered.

1902. Wegscheider very effectively replied that, as the equation
 given by Euler is a self-evident identity, it cannot possibly lead to
 a reaction velocity.

1903. In spite of this, Kullgren endorsed Euler's theory and en-
 deavoured to calculate the temperature coefficient of inversion from
 conductivity measurements of purified water (Kohlrausch) and of solu-
 tions of cane sugar (Madsen) at various temperatures. Euler and Kull-
 gren, however, appear to be unable to agree as to what the ions of sugar
 really are.⁷

1904. Goldschmidt has also accepted the theory and has applied it to
 the catalysis of esters by acid, which he imagines to be an ionic
 action.

1904. Abegg has hopes that Euler will be able to offer a better proof
 of his hypothesis based on Walker's theory of amphoteric
 electrolytes.

¹ *Ofvers Vet. Akad.*, 1900, 57, p. 267.

⁴ *Ber.*, 34.

⁶ *Zeits.*, 39.

² *Zeits.*, 32.

³ *Zeits.*, 36.

⁵ *Zeits. Physik. Chem.*, v. 37.

⁷ *Vide* Section F.

1902. Ostwald has spoken benignly, although without enthusiasm, of this theory of catalysis of Euler's, remarking that it cannot be applied to cases where a mixture of two electrolytes produces a greater effect than the sum of their two separate effects.

E 3.—Miscellaneous Theories of Sugar Inversion.

1872. Dubrunfaut maintained that cane sugar partakes of the nature of a salt, the glucose being basic. Inversion, according to him, is a purely chemical action of the acid used.

Spohr, who supported the Clausius-Williamson dissociation hypothesis, appeared to think that the sugar is inverted by nascent radicles of H and (OH), the number of which was increased by the presence of an acid.

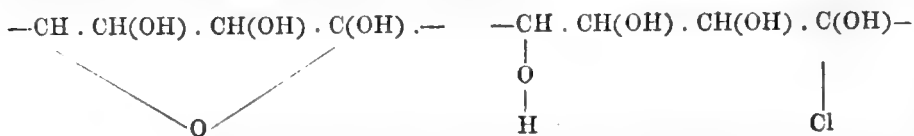
1889. Ostwald,¹ on the other hand, expressed the opinion that 'the affinity of the acid for the alcoholic hydroxyls of the glucose and levulose produced acts in a predisposing fashion,' hence the presence of acid quickens inversion. This view was published about the same time as Arrhenius's theory (*vide* E 1, above).

1890. An important contribution to this subject was made by Wohl, who advanced a new theory of inversion. Wohl showed that the optical inversion of cane sugar by acids proceeds further if the quantity of acid used be small than if it be great. It was found that the rotation fell to a minimum and then on further heating reverted. The reducing power undergoes a similar change simultaneously. That is to say, a slow secondary change was occurring, whereby the monoses were being coupled up again to some biose substances with less reducing power.² Wohl showed that under his conditions it was mainly the levulose which reverted and he isolated a dextrin which on hydrolysis gave levulose again.

1890. In the same year isomaltose was prepared by E. Fischer by the action of hydrogen chloride in excess on glucose in the cold.

1904. Wohl's work has also received support from Noyes and his pupils, who have investigated the hydrolysis of maltose with dilute acid and found that reversion of the glucose occurs. Armstrong and Caldwell have, in fact, measured the rate of reversion of glucose and galactose.³

Wohl explained the reversion by supposing that the acid combines with the lactonic ring of the monoses, thus :—



the chlorhydrin produced giving a disaccharide on losing hydrogen chloride. In inversion, the hydrogen chloride is supposed to combine with the

¹ *General Chemistry*, Walker's translation, 1889, p. 355.

² This agrees with Meissl (*J. Prakt. Chem.*, 1882 (2), 25, p. 127) and with Winston (*J. Analyt. Chem.*, 1888, 2, p. 152), who both record the reversion of glucose with dilute HCl at high temperatures.

³ See also E. F. Armstrong, *Proc. Roy. Soc.*, 1905, 76, p. 592.

levulose part of the cane sugar; the compound of sugar and acid (for no obvious reason) then at once parts with glucose, leaving the chlorhydrin of levulose behind. This latter gives levulose or a disaccharide, according to circumstances.

1894. Donath, supposing from his experiments at 120° that glycerol inverts sugar, put forward the theory that the glycerol exists as a hydrate, the nascent free water molecules from which are the active agent in hydrolysis.

1894. Bordt, however, has shown that Donath's experimental work was unsound and that glycerol really retards inversion instead of promoting it.

1901. Rohland, in a theoretical paper, put forward the view that nascent molecules of water formed from H and OH ions bring about the inversion. Any cause, such as the presence of an acid, which increases the number of nascent water molecules formed in unit time, will also accelerate inversion.

1902. Noyes and Samnet, on the other hand, suggested in a footnote to a lecture on catalysis that the hydrogen ions are hydrated and that their water is more active than ordinary water molecules. The

1902. ions thus act merely as water carriers. Rohland claimed that this was his theory but the two are not by any means the same.

1904. Mellor and Bradshaw have discussed inversion mathematically with regard to the secondary changes which occur, with reference especially to the bi-rotation of glucose and levulose. There is, however, no experimental evidence of such secondary actions occurring after inversion.

E 4.—*The Addition Theory of Sugar Inversion.*

1901. Ostwald has admitted that 'there is nothing in the laws of chemical kinetics to disprove the addition theory (of chemical change) but it must be proved that the partial actions proceed more rapidly than the main action.'

It will be seen that Wohl's theory is essentially an addition theory of inversion. If from other considerations it appears highly probable that the addition theory is the correct explanation, the fact that a 'mono-molecular' law is followed ought to be taken as a sufficient indication of the correctness of the assumption mentioned by Ostwald.

The addition theory has been developed systematically by Dr. E. F. 1904. Armstrong and the author in a comparative study of the action of acids and enzymes on various sugars. The theory put forward was that the sugar enters into some kind of combination with the acid and some water molecules. An 'active system' thus arises which fulfils all the requirements of Arrhenius's 'active sugar' and which breaks down into invert sugar and hydrated acid according to a mono-molecular mass action.

As only a small proportion of the acid molecules are engaged at any moment, the acid is usually in large excess. If, however, very small quantities of acid are used, the sugar is in excess, so that during the first part of the hydrolysis Wilhelmy's Law is not followed but the change approximates to a linear function of the time, as is frequently observed in the case of enzyme action. It was further shown that the effect of neutral substances, the influence of temperature and concentration, could be very satisfactorily explained on this hypothesis.

F.—*Influence of Temperature on the Rate of Inversion.*

The velocity of inversion increases with rise in temperature. This fact was discovered by Wilhelmy, by Löwenthal and Lenssen and by Urech independently.

1883. Urech gave an empirical equation to represent the influence of temperature, and at a later date showed how very great this effect

1884. is by means of curves.

1885. Spohr also deduced an equation for the influence of temperature from his results.

1887. This was criticised by Urech, who now made use of an exponential equation [which he showed to be the same as Van't Hoff's equation deduced theoretically for the alteration of the position of a chemical equilibrium with temperature].

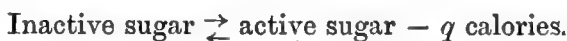
1890. Hammerschmidt has also given an empirical equation to represent the influence of temperature on sugar inversion.

1889. Arrhenius, too, adopted the Van't Hoff equation, viz. :—

$$\rho t_2 = \rho t_1 \epsilon^{\frac{q}{2}} \cdot \frac{T_2 - T_1}{T_1 \cdot T_2}$$

Where $\left\{ \begin{array}{l} \rho t = \text{velocity at temp. 't.'} \\ T = \text{absolute temp.} = (273 + 't') \\ q = \text{thermal value of the change.} \end{array} \right.$

He showed that it holds not only for the inversion of sugar but also for a large number of other catalytic actions.¹ Now, seeing that Van't Hoff's equation does not represent the effect of temperature on the velocity of an action but on the position of an equilibrium, it must be conceded that there is some kind of equilibrium to be disturbed in all these reactions. Arrhenius supposes that only a certain proportion of the sugar is susceptible to hydrolysis at any given moment. This is called the 'active part' and the equilibrium is :—



No other explanation suffices to account for the great effect of a rise in temperature, the increase in molecular velocity being only $\frac{1}{6}$ per cent., of 'ionisation' of the acid .05 per cent. and of fluidity 2 per cent. per degree rise in temperature. The hypothetical active sugar, which has a calculated heat of formation of 25,600 cal., is supposed to be formed by intramolecular change or by combination of the inactive sugar with water. Additional non-electrolytes, neutral salts, and even the acid itself, are supposed to increase the amount of 'active sugar.'

1900. Lippmann objected to this theory on the ground that it was impossible to imagine the nature of the active part, and he could not understand why so much heat should be required for its formation. This objection is certainly a serious one, as any internal rearrangement of the molecule of cane sugar would involve a very small heat change;

1897. Brown and Pickering have shown that the heat of dissolution of cane sugar is only -954 cal. per equivalent and the heat of inversion itself is but 4,560 calories.

1901. Euler, on the other hand, has interpreted Arrhenius's 'active part' as meaning the sugar which is dissociated into ions of glucose

¹ H. Ley (1899) has shown that this equation holds good up to 100° C.

and fructose. From this hypothesis it follows that 'q' is the heat of ionisation of water plus the heat of ionisation of sugar. Thus:—

$$\begin{aligned} 'q' &= 25,600 = Q_{\text{sugar}} + Q_{\text{water}} = Q_{\text{sugar}} + 13,600 \\ \text{Heat of ionisation of sugar} &= Q_{\text{sugar}} = 12,000 \text{ calories} \end{aligned}$$

1902. Kullgren suggested that the effect of temperature on the product $C_A C_B C_H C_{OH}$,¹ being the resultant of the separate effects of temperature on the ionisation of water and of sugar, might be calculated if the latter were known.

1903. Later on he made use of Kohlrausch's conductivity values for water and Madsen's measurements for cane sugar in presence of alkali² and calculated a temperature coefficient for the inversion velocity of the same order of magnitude as the experimental value.

1904. Euler objected that Kullgren's 'ions' of cane sugar, $\overset{+}{H}$ and $(C_{12}\overset{-}{H}_{21}O_{11})$, would lead to the result that alkali could cause in-

version to take place. The ions must therefore be $(C_{12}\overset{+}{H}_{21}O_{10})$ and $(\overset{-}{OH})$.

1905. Kullgren retorted that if the ions are as supposed by Euler, acids instead of promoting inversion ought to stop it! He therefore falls back upon the original *glucoseions* and *levuloseions*.

1898. The Van't Hoff equation holds not only for the inversion of cane-sugar but also for the hydrolysis of maltose (Sigmund) and of

1904. lactose (Armstrong and Caldwell); this goes to show that there must be some kind of 'active part' in these cases also.

The latter authors suggest that the 'active part' should be interpreted as being the sugar molecules which at any moment are in combination with acid molecules. Thus 'q' is the heat of formation of an active system composed of sugar, acid and a certain number of water molecules, which ultimately decomposes into invert sugar, acid and water (*vide* Section E).

G.—Influence of Concentrations of Interacting Molecules.

G 1.—Concentration of Acid.

Generally speaking, if the amount of sugar and the volume of the solution be kept constant, the more acid there is present the quicker the inversion proceeds.

1883. It was observed by Urech that as the concentration of the acid increases, the invertive power increases out of proportion more

1884. quickly. He published a curve showing the effect of acid concentration. The same lack of proportionality between the acid

1885. concentration and the rate of hydrolysis was noted by Ostwald. The molecular catalytic activity of an acid increases whilst its molecular conductivity decreases, as may be seen from the following table from Ostwald's paper:—

Inversion of 20-per-cent. Sugar Solution by HCl.

Dilution	Molecular Invertive Power of Acid	Molecular Conductivity
2	41.0	294
10	33.4	326
100	31.3	334

¹ *Vide* Section E 2.

² That is, considering sugar as an acid substance.

Ostwald supposed that the two sets of values ought to be proportional but that some secondary influence was at work in the case of the inversion numbers similar to the influence of the sugar itself (*vide* G 2). With weak acids the agreement is better.

With the object of strengthening the ionic theory of catalysis (Arrhenius), Palmaer has made a careful comparison between the invertive power and conductivity of very dilute hydrochloric acid. He eliminated, as sources of error :—

1. Neutralisation of the acid by the ash in the sugar, by recrystallising the sugar many times.
2. Bi-rotation of the invert sugar, by taking his polarimeter readings at 48° C, the temperature of the thermostat.
3. Dissolution of the glass, by using a platinum vessel.

Fair proportionality was found to exist between the rate of inversion and the concentration of the hydrogen ions for strengths less than $\frac{1}{100}$ th normal HCl. His conclusions are open to criticism on the ground of his use of platinum vessels. He himself thought that no catalytic oxidation would occur as he worked at 48°, whereas Ráyman and Šulc's results were obtained at 80° C. (*vide* Section B 6). Yet it is a fact, as conductivity measurement will show, that some oxidation of glucose by platinum does occur even at 18° C.¹

1898. W. A. Smith arrived at the same conclusion as Palmaer for the temperature 100°, with the reservation that with weakly dissociated acids the accelerating influence of the undissociated material must be taken into account.

G 2.—*Influence of Initial Concentration of Cane Sugar.*

Fleury, who worked with weight-normal solutions, showed that on altering the initial quantity of sugar very little alteration occurs in the rate of inversion.

1882. Urech, however, endeavoured to show that a concentrated sugar solution is more slowly inverted than a weak one. His evidence is not convincing.

1885. Ostwald, on the other hand, showed that in volume-normal solution the relative rate of inversion is enormously higher in a '40 per cent.' cane-sugar solution than in a '4 per cent.' solution.

1886. This was confirmed by Spohr. The latter author saw that in these cases, as more sugar is present it displaces more water and hence the concentration of the acid is virtually greater. He made three experiments with weight-normal sugar solutions in deci-normal acid and obtained practically the same velocity when the sugar concentration was considerably varied. The great importance of this point does not appear to have been realised by Spohr and has been generally overlooked.

1897. Cohen was also on the same track when he suggested that the deviations of the inversion velocity in concentrated solutions are due to the same cause as the deviations from Boyle's law for gases, *viz.*, the actual bulk of the sugar molecules. He gave the equation :—

$$K_{20\%} : K_{40\%} :: \frac{1}{100-b_{20}} : \frac{1}{100-b_{40}},$$

¹ Vide *Proc. Roy. Soc.*, 1906, **78**, p. 283.

where K_{20} per cent. is the inversion velocity in a 20-per-cent. solution and b_{20} is the actual volume of the sugar molecules in 100 cc. of a 20-per-cent. solution. That is to say, 'the rate of inversion is inversely proportional to the space in which the molecules move.'

He showed that this theory was in fair numerical agreement with the results already published by Ostwald.

1898. Arrhenius, however, ignored Cohen's suggestion when he pointed out in the next year that the rate of inversion, *ceteris paribus*, follows the osmotic pressure of the sugar in solution. That is to say, the increase in inversion velocity with sugar concentration is to be explained by the abnormally high osmotic pressures of strong solutions. The amount of 'active sugar' (*vide* Section F) is supposed to be proportional to the osmotic pressure of the sugar molecules.

1906. The author has recently demonstrated that the supposed abnormality of strong sugar solutions is almost non-existent when a rational method of experiment is adopted, viz., the use of weight-normal solutions. In this case, when the concentration of the sugar is varied from 85.5 to 342 grams per 1,000 grams of water, the inversion velocity increases only 3.3 per cent. instead of 38 per cent., the increase observed when volume-normal solutions are used, *i.e.*, solutions in 1 litre.

It is probable that the inversion velocity and the osmotic pressure do run closely parallel in both volume- and weight-normal solutions. Morse and Frazer have recently shown that in weight-normal solutions the molecular osmotic pressure is not affected by changes in concentration. The author has ventured to suggest, on the basis of his determinations, that some of Morse and Frazer's values¹ for concentrated solutions are a little too low; the results obtained by Lord Berkeley and Mr. Hartley by direct measurement of osmotic pressure appear to support this view.

H.—*Influence of added Non-electrolytes on Inversion Velocity.*

H 1.—*Non-electrolytes in General.*

The effect of various non-electrolytes on inversion, such as glucose, glycerol, mannitol, &c., acquires interest from a comparison of their effects in the case of the action of invertase.

Briefly put, almost any 'foreign' substance affects the velocity of inversion by acids, whilst the activity of an enzyme is only affected in cases in which the added non-electrolyte happens to be one of the products of the inversion.² Thus glucose retards the action of maltase on maltose, whilst fructose has no effect.

On the other hand, moderate amounts of glucose, fructose,³ and glycerol, in volume-normal solution, accelerate the inversion of cane sugar by acid, whilst in weight-normal solutions some non-electrolytes accelerate and some retard.

1889. Arrhenius supposed that the addition of non-electrolytes increased the amount of his 'active sugar' in (volume-normal) solution.

¹ Morse and Frazer, *Am. Chem. Journ.*, 1905, 34, p. 1; 1906, 36, p. 39. Berkeley and Hartley, *Phil. Trans.*, 1906, A 200, p. 481.

² *Vide* E. F. Armstrong, *Proc. Roy. Soc.*, 1904, 73, p. 520.

³ Armstrong and Caldwell, *ibid.*, 1904, 74, p. 200.

1894. Bordt, however, showed that inversion is slower in presence of moderately large amounts of glycerol.
1898. At high temperatures (100°) glucose is said to act as an acid and to promote inversion in cane-sugar solutions. Thus Geerlings found that a mixture of glucose and a neutral salt could cause inversion at high temperatures and he attributed this action to the partial liberation of HCl from the KCl by the acidity of the sugar. W. A. Smith has confirmed this result. The explanation offered, involving an assumption of acidity on the part of glucose, seems to be open to doubt when it is remembered how easily the carbohydrates are oxidised to acid products under these conditions. Kullgren, however, arrived at the same conclusion on finding that various sugars retard the hydrolysis of ethyl acetate by NaOH. Cohen has measured the extent of this retardation for various sugars and has found that mannitol has very little effect in comparison with the others. Hence Cohen, too, adopts the idea that the sugars are acidic. He promised to discuss the problem mathematically, but the paper has not yet appeared.
1901. Lippmann cannot admit that the sugars are acid in nature.
1904. Mellor and Bradshaw have noted that the addition of glucose and fructose beforehand, although it affects the absolute value of the velocity, does not impair the constancy of the value of K in any one experiment.
1901. Henri and des Bancel's claimed to have established that the simultaneous catalysis of methyl acetate in the same solution does not appreciably affect the rate of inversion of cane sugar at 29°, whilst the hydrolysis of the ester itself is somewhat faster in presence of sugar.
1901. A far more comprehensive research on the same subject was published simultaneously by Coppadoro. It was shown by the latter that Henri and des Bancel's result was only valid for volume-normal solutions containing a large proportion of acid ($\frac{N}{2.5}$ HCl). When, however, dilute acid is used ($\frac{N}{12.5}$ and $\frac{N}{25}$), the hydrolysis of the cane sugar is considerably retarded by the methyl acetate, but the hydrolysis of the ester is itself much accelerated. This acceleration, however, is merely due to the displacement of water by the sugar in the volume-normal solutions used. Coppadoro showed that in weight-normal solutions the presence of cane sugar has not the slightest effect on the hydrolysis of methyl acetate. [Hence the viscosity of the sugar has little effect on the rate of catalysis of methyl acetate and it follows that Kullgren's result (*see above*) is probably due to the formation of sucrales.]
- Methyl acetate may be supposed to act in the same way as alcohol (*see below*, H 2) in retarding the inversion of sugar. There is thus no support for the separation of acid catalysis from enzyme action in Henri and des Bancel's classification.
1906. A complete discussion of the *modus operandi* of neutral substances, hitherto considered in a very superficial manner, has recently been published by the author. It is obvious that we must take into account (1) retardation by mechanical hindrance; (2) acceleration by combination of the added substance with water of hydration, thus concentrating the solution; (3) combination with the hydrolytic agent, thus

rendering it temporarily inactive; and also, in the case of volume-normal solutions, displacement of water by the neutral substance.

With regard to the first factor mentioned, it is difficult to estimate the extent to which mechanical hindrance affects inversion. Reformatsky's 1891. four experiments, showing that the catalysis proceeds as quickly in a solid agar-agar jelly as in pure water, do not appear to justify the importance which has been so often attached to them, whilst 1900. Levi's two experiments, showing that the presence of colloidal silicic acid does not affect the inversion velocity of sugar, are even less trustworthy. It seems probable, however, that the mechanical hindrance caused by one added molecule in some fifty-five molecules of solvent (a weight-normal molecular solution) would not be very great. It is usually more than compensated for by the dehydrating effect of the added molecules, for instance when the added molecules are glucose, lactose or acetic acid. With glycerol, however, the considerations numbered (1) and (3) are more potent than the dehydrating effect and the result is a retardation in weight-normal solutions.

In the case of enzymes, if the added molecules have a suitable configuration and combination occurs, a considerable retardation may be experienced, as acceleration by dehydration effects does not seem to come into play in this case and mechanical hindrance appears to have little effect.

H 2.—*Influence of Alcohol.*

The effect of alcohol on the rate of inversion has been more studied than that of any other substance; it differs from the effect of non-electrolytes in general, in that an acceleration is never observed, even in volume-normal solutions.

1891. Kablukow and Zacconi were the first to note that the effect of alcohol is to retard inversion. This retarding influence in the case of some acids is much more potent than in others.

1893. Wakeman confirmed this result and also noted that the molecular conductivity of the acid is also decreased, although not proportionately to the sacroclastic activity. Wakeman thought that the effect of alcohol was due to an alteration in the viscosity of the solution; if this were the case the activity of all acids should be proportionately diminished.

1898. The problem was further investigated by Cohen, who measured the conductivities of HCl in various strengths of alcohol over a wide range of dilutions. He concluded that as the inversion velocity is less in alcoholic solution, the number of hydrogen ions must be less. As his conductivity measurements led him to a different conclusion, he thought that perhaps the conductivity method does not give a trustworthy measure of the ionisation.

1899. In the next year Cohen showed that, even at high dilutions alcoholic (20 per cent. and 50 per cent.) solutions of HCl invert sugar more slowly than water solutions. Hence, as the acid is 'completely ionised' in the dilutions used, whether aqueous or alcoholic solutions be used, it follows that the alcohol does not necessarily alter the number of hydrogen ions but exerts a specific retarding action on the inversion.

1898. Meanwhile Arrhenius had laid down the ruling that alcohol decreases the amount of the active part of the sugar.

1901. Kullgren agreed that the retarding influence of alcohol on the hydrolysis of ethyl acetate¹ is also due to a diminution of the active part, but held that the influence of sugars on the same action is due to a different cause, viz., combination of the sugar with the alkali, thus rendering it inactive.

1906. The author has shown that the influence of alcohol is in no way peculiar in comparison with that of other non-electrolytes. In volume-normal solution, indeed, the introduction of small quantities of alcohol produces no diminution in velocity but in weight-normal solutions a diminution is always observed. The dehydrating effect of alcohol is thus completely overmasked by the diminution due to its combination with the acid to form alcoholates. The large solubility of HCl in alcohol and the formation of conducting solutions confirms the impression that alcoholates are easily formed. It is obvious that alcoholates will be formed with various acids to varying extents and hence the proportionate decrease in the case of sulphuric acid, for example, should not be the same as for hydrochloric—a result noted by Kablukow and Zacconi.

J.—*Influence of Neutral Electrolytes on Inversion Velocity.*

1862. It was first pointed out by Löwenthal and Lenssen that a neutral salt of an acid, although unable to effect any hydrolysis of itself, is able to increase the hydrolytic action of its parent acid. This property they attributed to the concentration of the acid by the salt, partly by displacement of water by virtue of its bulk and partly by the formation of hydrated salt molecules; also, possibly, to the formation of double salts.

1885. Spohr, who had helped Ostwald with his later measurements, further investigated the action of neutral salts and argued that Löwenthal and Lenssen's explanation that the salts stimulate the acids in virtue of their water-binding power is wrong, because he found that in the case of weak acids the presence of a neutral salt has an unfavourable effect.² Spohr also showed that the accelerating effect of a salt on a strong acid is less at a higher temperature. With bi-basic acids the case is complicated by the formation of acid salts. The acceleration is to be observed in weight-normal as well as volume-normal solutions.

1888. In his last paper Spohr gives further experiments on the influence of salts on the inversion of sugar and also on the saponification of ethyl acetate by KOH. He then attempts to explain the action of salts on the Williamson-Clausius dissociation hypothesis, supposing that the inversion is brought about by nascent H and OH radicles.

1891. Speransky showed that the addition of a salt of a strong acid, such as NaCl, can increase the rate of inversion by a weak acid like acetic or lactic acid.

1889. Arrhenius, in his well-known memoir, explained the action of a neutral salt as increasing the amount of 'active sugar' and he endeavoured to show that this property is an additive one for the ions of

1898. the added salt. Later on he stated more definitely that the neutral salt increases the osmotic pressure of the sugar in solution and, consequently, the 'active part' also. In support of this idea he quoted Abegg, who had shown that a mixture of two substances frequently has

¹ *Zeits. Physik. Chem.*, 37.

² *Vide Speransky, infra.*

a larger freezing-point depression than the sum of their separate depressions. The mechanism by which the osmotic pressure of the sugar is increased by a salt is not stated. Arrhenius also discussed Speransky's results on the same basis.

That the condition of sugar in solution is in some way altered by the presence of electrolytes can be seen readily from the results obtained by Bornträger and also Farnsteiner, who both state that the optical rotation of sugar is considerably changed by the mere presence of a neutral salt in solution.

1900. Euler, who has discussed the action of neutral salts with reference to his ionic theory of catalysis, explained that the neutral salt functioned by increasing the osmotic pressure of the ions of sugar and also the reactive capacity of the water. The former effect may result from an increase in the ionising power of the water and the latter from an association of the salt ions with the ions of the water.

1904. He has latterly added another alternative—namely, that a neutral chloride increases the amount of dissociated saccharose chloride. Armstrong and Caldwell, on the other hand, revert to the old explanation that neutral salts, like all other accelerating 'foreign' materials, remove water from the system and concentrate the solution. It was shown by them that KCl accelerates the action of HCl in hydrolysing lactose. The theory has been developed by the author in a recent paper, with the object of obtaining a numerical value for the degree of hydration of various salts. The method adopted was to measure the amount of additional water which must be put to a weight-normal solution containing a neutral salt in order to reduce the reaction velocity to the value it would have if no salt were present. The values determined in this way were as follows: $\text{NH}_4\text{Cl} \cdot 10\text{H}_2\text{O}$; $\text{KCl} \cdot 10\text{H}_2\text{O}$; $\text{NaCl} \cdot 13\text{H}_2\text{O}$; $\text{BaCl}_2 \cdot 19\text{H}_2\text{O}$; $\text{CaCl}_2 \cdot 22\text{H}_2\text{O}$.

Should these rational numbers be substantiated by other methods, the theory must be held to be established.

K.—*Influence of High Pressures on the Inversion Velocity.*

Wilhelmy came to the conclusion that the inversion velocity is not affected by external pressure on the solution.

1850. Röntgen, however, working with much higher pressures, up to 500 atmospheres, found that the rate of inversion by HCl is distinctly less under a high pressure. This seemed all the more remarkable as the rate of diffusion of salts is increased by pressure. Röntgen therefore concluded that the acid must be less ionised under a high pressure. This conclusion is directly opposite to the result already arrived at by Fink¹ by conductivity methods, whilst Tamman² also from his measurements, formed the opinion that, if anything, the degree of ionisation is slightly increased by 500 atmospheres' pressure. Fanjung³ arrived simultaneously at the same result—namely, that the ionisation is slightly increased, whilst the actual conductivity is considerably augmented, by high pressure.

1896. Rothmund repeated Röntgen's observations. The decrease in inversion velocity is 1 per cent. per 100 atmospheres with various strengths of nitric and hydrochloric acid as catalysers. Seeing that the

¹ *Wied. Ann.*, 26, p. 481.

² *Zeits. Physik. Chem.*, 14, p. 444.

³ *Ibid.*, p. 673.

'ionisation' and 'ionic mobility' are both increased by high pressure and in fact the catalysis of methyl acetate is also accelerated, Rothmund concluded that the effect of high pressure is to decrease the amount of 'active part' of the cane sugar.

1896. Stern has also confirmed Röntgen's observations, showing that the effect is independent of the temperature and concentrations. In the case of weak acids, such as phosphoric and acetic, a high pressure increases the reaction velocity.

1897. Bogojawlensky and Tamman expressed the effect of pressure on inversion velocity by a differential equation and showed that in the case of methyl acetate catalysis, as noted by Rothmund, a high pressure is favourable. The effect of pressure on weak agents is much more pronounced than on strong ones. These authors estimate that under some 50,000 atmospheres' pressure all acids and bases would be of equal strength.

1898. The unfavourable effect of pressure has also been noticed by Ráyman and Šulc in the so-called catalytic inversion by platinum black.

1906. Recently the author has suggested that the rate of attack of the acid on the cane sugar is diminished by the hydration of the sugar molecules. A high pressure should increase the degree of protective hydration and hence diminish the inversion velocity.

L.—Measurement of Hydrolytic Dissociation.

The salt of a weak acid with a strong base or of a strong acid with a weak base is partially decomposed in solution, giving free acid and base. In order to estimate the amount of this hydrolytic decomposition it is desirable to use a method which does not involve disturbing the equilibrium during the measurement. For the former case the catalysis of an ester has been applied by Schields,¹ whilst for the latter the inversion of cane sugar is a convenient method.

1889. The first experiments of this kind were made by Walker,² who measured the rate of catalysis of methyl acetate by the hydrochlorides of very weak bases, such as thiazol and urea. The first measurements

1893. by means of cane sugar were made by Bruner, who estimated the amount of hydrolytic decomposition of a large number of salts at 40° and in varying concentrations. In the case of ferric chloride the hydrolysis is especially large, amounting to 14·7 per cent. in a $\frac{1}{20}$ molecular solution. Bruner's work was overlooked until it was republished in 1900.

1895. The same method was applied by Walker and Aston to the hydrochlorides of a number of organic bases varying from pyridine (2 per cent. hydrolysis) to thio-urea (97 per cent. hydrolysis) and to several inorganic nitrates, such as aluminium nitrate, which is hydrolysed to the extent of 0·7 per cent. in half-normal solution. The method, as these authors observe, is subject to an unknown error, due to the influence of the undissociated salt on the rate of inversion (*vide* Section J).

1896. Cohnheim made use of Walker and Aston's method to measure the basicity of various albumins. His results have been criticised

1898. by Burgarsky and Liebermann, on the ground that the increase in viscosity caused by the presence of an albumin would explain the

¹ *Zeits. Phys. Chem.*, 1893, 12, p. 167.

² *Ibid.*, 1889, 4, p. 319.

- effect measured equally well. This, however, is contrary to the conclusion of Reformatsky and also Levi (*vide* Section H). Long extended
1896. Béchamp's observations on inversion by certain feebly stable salts, such as ferrous chloride and cadmium chloride. He calculated the degree of hydrolysis of various salts at 85° C. by Walker and Aston's method, the influence of the salts themselves on the rate of inversion by the free acid being, as he remarks, neglected. This work was further extended
1899. by Kahlenburg, Davis and Fowler, who measured the hydrolysis of various salts by means of sugar, using the freezing-point method in the case of coloured salts. The order of basicity of the metals as determined in this way is much the same as their 'solution tensions,'
1899. aluminium, however, forming a notable exception. Ley, in the same year, published a research on similar lines. Some salts, according to Ley, such as LiCl, KCl, MgCl₂, have no invertive power at all; whilst others, such as Al₂Cl₆, cause considerable inversion and also have the power to hydrolyse methyl acetate. The values obtained for the hydrolytic decomposition of aluminium chloride in $\frac{N}{32}$ solution are 8.04 per cent. by the sugar-inversion method and 8.8 per cent. by
1903. the methyl acetate method. Walker and Wood made a careful comparison of the two methods and found that if a correction were applied for the accelerating effect of the salt in the case of cane
1901. sugar, the two methods of estimating gave results in very close agreement. This subject has already been reported on by Farmer to the British Association in 1901.
1902. Kullgren observed that inversion at 100° by salts such as MnCl₂ or CdCl₂ does not follow a mass-action curve because an acid is progressively formed from the sugar itself. With Al₂Cl₆ a better constant is obtained, because the disturbing effect is by comparison smaller.

M.—*Hydrolysis of Sugars other than Cane Sugar.*

- Compared with the facility with which cane sugar is hydrolysed, all the other biose sugars and the glucosides are much more difficult of attack.
1882. This was noted by Meissel, who found that maltose is intermediate in stability toward acids between cane sugar and lactose.
1885. Urech discovered the same fact and explained the different stability of the three sugars by the 'gradation from fructose to galactose through glucose.'
1886. Bourquelot, who was in ignorance of the two foregoing researches, also showed that maltose is enormously more stable than cane sugar towards acids. A saturated solution of carbon dioxide at 38° can invert cane sugar but apparently is without action on maltose. Sigmund
1898. measured the rate of hydrolysis of maltose between 63°·7 and 83°·8. The action follows Wilhelmy's Law and when the temperature is varied the velocity varies according to Van't Hoff's equation. The initial volume-normal concentration of the maltose has considerable influence, as in the case of saccharose (*vide* Section G 2).
1904. Armstrong and Caldwell studied the rate of hydrolysis of lactose and maltose at 60°, 74° and 99 C°. The hydrolysis follows Wilhelmy's Law and is in every way similar to that of cane sugar, except that it proceeds much slower. The effect of concentrations of sugar and

acid, of neutral salts and of temperature is the same. The relative facility of hydrolysis of the three sugars is:—

Milk-sugar	1·0
Maltose	1·27
Cane sugar	1240·0

a result which is in harmony with the earlier statements.

1904. Noyes and others have also studied the hydrolysis of maltose at 100° and 110°. They found a considerable amount of reversion to occur, which Sigmund did not mention; this was also shown to be the case by Armstrong and Caldwell and is in harmony with Wohl's observations (*vide* Section E 3).

1895. The hydrolysis of the glucoside salicin, as measured by Noyes and Hall, proceeds at a rate which is of the same order as that of maltose. The velocity constant in this case also is influenced by concentration of the acid and the salicin in the same way as for cane sugar.

1904. An interesting comparison has more recently been made by E. F. Armstrong of the relative rates at which various glucosides and galactosides are hydrolysed. He gives the following table of inversion velocities:—

	74°·1	74°·8
α -Methyl glucoside	0·0100	0·0114
β -Methyl glucoside	0·0179	0·0220
α -Methyl galactoside	0·0542	0·0650
β -Methyl galactoside	0·0884	0·1061
Salicin	0·0601	
Maltose	0·0740	

The hydrolysis of the glucoside amygdalin, which the author is at present investigating, is comparable with that of the methyl glucosides in velocity.

1903. The hydrolysis of tri-saccharides has been discussed by Wogrinz from a mathematical standpoint, but no experimental work has hitherto been published on the topic.

1896. The hydrolysis of starch by dilute acid under pressure at high temperatures has been studied by Rolfe and Defren.

The interest of these observations on various sugars lies partly in the comparison of the stability of the various sugars, partly in a comparison with the velocity of enzyme hydrolysis (*vide* Section N) and, lastly, in a comparison of the activities of various acids in the several cases.

The following table has been compiled from the above-mentioned researches:—

Sugar Hydrolysed	Temp.	Relative Activities of the Acids			
		HCl	H ₂ SO ₄	H ₂ C ₂ O ₄	β Camphor-sulphonic (Reychler)
Saccharose	25	100	53·7*	18·2	89·8
Salicin	95	100	49·9	23·3	—
Maltose	74	100	40·5	14·1	—
Lactose	60·1	100	47·7	—	68·6
(Conductivity)	25	100	61·9	19·7	—

* By a curious slip the square root of this value, $\sqrt{53·7} \times 10 = 73·2$ was given by Ostwald and has been faithfully transmitted by all the text-books.

It has been from time to time pointed out by various observers that the relative strengths of the acids depend on the sugar by means of which the comparison is made, and even with the same sugar the ratio is different at different temperatures; it is difficult to see how these facts can be reconciled with the hydrogen ion theory of sugar catalysis.

N.—*The Analogy between Acid and Enzyme Catalysis.*

It was emphasised by Omeis that, although the effect of temperature is different in the two cases, yet there is no essential difference between enzyme and acid catalysis. Ostwald has more recently stated that 'the action of enzymes is entirely analogous to that of catalysts in general.'

Granting that the analogy exists, it is necessary to consider whether we ought to modify our opinion of the manner in which either acid or enzyme act in order to bring the two cases into agreement.

With regard to the action of enzyme, even Euler has not attempted to apply an ionic explanation; on the other hand, there is no parallel among the numerous theories of acid catalysis for the enzyme radiation theory of Barendrecht.¹ The only hypothesis which is equally applicable to the two cases is the addition theory. In the case of enzymes the evidence is strongly in favour of this view; but in the case of acids, as the foregoing pages will have demonstrated, the issue is not so simple.

The 'active system' theory, as Dr. E. F. Armstrong and the author have shown, is not at variance with any of the known facts of catalysis by acids, whilst the alternative ionic explanation is beset with difficulties.

They have stated that the difference in behaviour of acids and enzymes respectively as hydrolytic agents 'is due mainly if not wholly (1) to the superior affinity of the enzymes for the carbohydrates, (2) to the very different behaviour of the two classes of hydrolysts towards water, which is a consequence of the crystalloid nature of the one and the colloid nature of the other.' The amount of water present appears to have very little influence on the activity of an enzyme, whilst in the case of acids it is a very important determining factor in the rate.

On the other hand, the enormous activity of a few molecules of enzyme, compared with that of the strongest acids, is to be attributed to the above-mentioned causes, whilst the highly specialised nature of enzyme action points to a more intimate combination with the sugar. The differences are differences only of degree.

[Papers published since 1900 on this subject and those appearing in the future are to be found classified together in the D (Chemistry) volumes of the 'International Catalogue of Scientific Literature,' under the headings D 1820, Hydrolysis of Cane-sugar, and D 7090, Hydrolysis.]

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B5	1892	Bach . . .	'Z. Phys. Chem.,' 9, p. 251.
H2	1893	Wakeman . . .	'Z. Phys. Chem.,' 11, p. 49.
L	1893	Bruner . . .	'Wszechswiat,' 23, p. 365.
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B4	1894	Noyes . . .	'Z. Phys. Chem.,' 13, p. 417.
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M	1895	Noyes and Hall	'Z. Physik. Chem.,' 18, p. 240.
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B6	1897	Ráyman and Sulc	'Centr.' (ii.), p. 476.
G2	1897	Cohen . . .	'Z. Phys. Chem.,' 23, p. 442.
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B6, K	1898	Ráyman and Sulc	'Centr.' (i.), p. 608.
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G2, H2, J	1898	Arrhenius . . . (reprint)	'Bihang til Svenska Vet-Akad.,' 24 (ii). 'Z. Phys. Chem.,' 28, p. 317.
H1	1898	Kullgren . . . (revised)	'Bihang til Svenska Vet-Akad.,' 24 (iii). 'Z. Phys. Chem.,' 37, p. 613.
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The Faunal Succession in the Carboniferous Limestone of the South-west of England.—Interim Report of the Committee, consisting of Professor J. W. GREGORY (Chairman), Dr. A. VAUGHAN (Secretary), Dr. WHEELTON HIND, and Professor W. W. WATTS, appointed to enable Dr. A. Vaughan to continue his Researches thereon.

THE Committee beg leave to report that Dr. Vaughan is making satisfactory progress with the investigation of the zonal subdivision of the Carboniferous Limestone. It is not yet possible to submit a full report as to the results. The following interim report shows the nature of his investigations.

Dr. Vaughan is especially investigating the zonal classification of the highest beds of the Avonian series with a view to establishing zones above the upper Dibunophyllum zone. Material has been collected for this purpose from Rush County, Dublin, by Dr. C. A. Matley, and described by Dr. Matley and Dr. Vaughan in the 'Quarterly Journal' of the Geological Society, vol. lxii., May 1906, pp. 273-323. Further work in the same area will be done by the authors during the autumn of this year.

At Gower the Avonian beds have been examined by Mr. E. E. L. Dixon and Dr. Vaughan.

Material has been collected by Dr. Vaughan at Pateley Bridge in Yorkshire, and by Dr. C. A. Matley in Fifeshire.

Dr. Vaughan has also been investigating the value of brachiopods and corals for zonal work in the Carboniferous Limestones, and a paper upon this subject by him is now in the press.

The Committee apply for reappointment, with the title 'Committee to enable Dr. A. Vaughan to continue his Researches on the Faunal Succession in the Carboniferous Limestone in the British Isles,' and the allotment of the unexpended balance of the grant.

Investigation of the Fauna and Flora of the Trias of the British Isles, Fourth Report of the Committee, consisting of Professor W. A. HERDMAN (Chairman), Mr. J. LOMAS (Secretary), Professor W. W. WATTS, Professor P. F. KENDALL, and Messrs. H. C. BEASLEY, E. T. NEWTON, A. C. SEWARD, and W. A. E. USSHER. (Drawn up by the Secretary.)

[PLATES II. AND III.]

REPORTS have been received from Dr. A. Smith Woodward, F.R.S., giving a full description of *Rhynchosaurus articeps*, and from Mr. H. C. Beasley dealing with some new types of footprints recently found at Storeton and Hollington.

The Committee wish to express their thanks to the Museum authorities at Shrewsbury for kindly allowing the valuable slabs of *Rhynchosaurus* in their collection to be sent to the British Museum for examination.

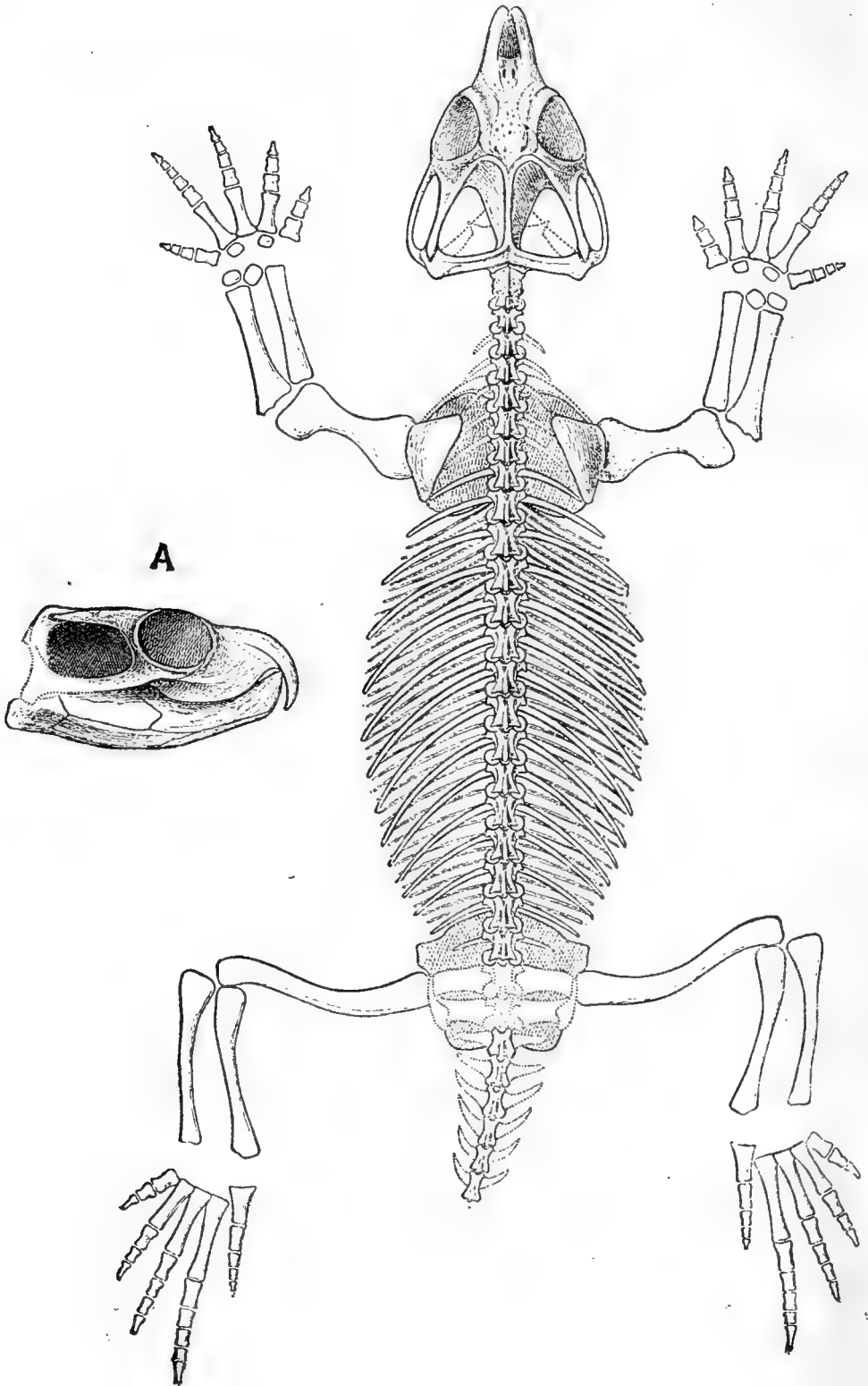
In the early part of this year the footprint-bed at Storeton, Cheshire, was worked, and a magnificent series of slabs with footprints was obtained.

Mr. C. Wells, the proprietor of the quarries, has taken special pains to raise the slabs without injury, and has kindly afforded every facility for their examination. A few new forms have come to light, but the chief value lies in the fact that the prints are in so perfect a state that even the claws and the marks of the epidermal covering of the feet are clearly shown.

So great an assemblage of footprints has probably never been seen before. It is impossible to describe the footprints adequately this year, but if the Committee is reappointed it is hoped to give a full description in next year's Report.

On Rhynchosaurus articeps (Owen).
By A. SMITH WOODWARD, LL.D., F.R.S.

Much has already been written concerning *Rhynchosaurus*, and many figures have been published of various parts of its skeleton. The descriptions, however, are scattered and not sufficiently systematic for convenient reference, while some of the figures are imperfect illustrations of essential points. A synoptical account of this reptile, based on a new study of the best specimens, may thus prove of value. Through the courtesy of the Committee of the Shrewsbury Museum, the original fossils described by Owen have been sent to the British Museum for comparison with the specimens described by Huxley. The following description has

Reconstruction of *Rhynchosaurus articeps* (Owen).—A. Side view of Skull.

therefore been made with the aid of all the most important materials hitherto discovered.

General Form.—As already remarked by Huxley (†) the general proportions of the head, trunk, and limbs of *Rhynchosaurus articeps* closely resemble those of the existing *Sphenodon punctatum*, but the extent of the long tail remains undiscovered. An outline-sketch of the upper aspect of the skeleton, so far as known, is given in the accompanying text-figure.

Skull and Mandible.—The skull is elongate-triangular in shape, with a flattened roof which imparts to it a depressed appearance. Its external surface is not ornamented, but many of the sutures between the constituent bones are obscure or unrecognisable. The orbits are large, occupying the greater part of the middle third of the skull, and are directed both outwards and upwards, with a conspicuously everted rim. The superior and lateral temporal vacuities are also relatively large; while the single narial opening is quite small and terminal, situated between the upper ends of the beak-like premaxillæ. The occipital and basioccipital regions of the cranium remain unknown; but the brain-case between the temporal fossæ is narrow, and the gently rounded parietal roof is surmounted by a prominent median longitudinal crest, from the anterior end of which a pair of less elevated though equally sharp ridges diverge outwards along the frontal-postfrontal sutures to the upper margin of the orbits. It is quite clear that there is no pineal foramen. The quadrate bone, which is well exposed from behind in the type specimen (S. 1¹), is deep and narrow, but not constricted above the trochlear lower end like the corresponding bone of *Sphenodon*. It is therefore probable that the quadrate was directly in contact with the quadrato-jugal throughout its depth, without any intervening postero-temporal foramen. The complete lower temporal arcade, consisting of the jugal and quadrato-jugal, has not hitherto been observed; but the shape of the triradiate jugal, which forms the orbital rim postero-inferiorly, shows that the arcade in question must have been present. The lower edge of the jugal below the orbit is everted, producing a short longitudinal ridge on the cheek. The upper temporal arcade is formed chiefly by the large postorbital bone, which is triangular in shape and only enters the hinder part of the orbital rim for a short space between the jugal and postfrontal. Remains of the squamosal, at the upper end of the quadrate in the type specimen, show that this element underlies the hinder end of the postorbital, and extends in the usual inwardly directed process towards the parietal. As displayed especially well in the type specimen, the roof of the facial region of the skull is indented with small pits, which are more or less irregularly disposed, but form a regular pair of rather deep depressions on the nasal bones. The frontal elements constitute a diamond-shaped area about as broad as long, and scarcely enter the orbital rim between the relatively large postfrontals and prefrontals. The nasals, which form the postero-superior boundary of the single narial opening, are excluded from contact with the maxilla on each side by the long and downwardly curved, spine-shaped premaxilla, which extends upwards to meet the prefrontal. The premaxilla is only loosely apposed to its fellow of the opposite side below the narial opening, where the pair together form the characteristic recurved beak, without any distinct trace of tooth-substance. The

¹ Specimens in the Shrewsbury Museum are marked S. with a numeral; those in the British Museum are marked B.M., followed by a register-number.

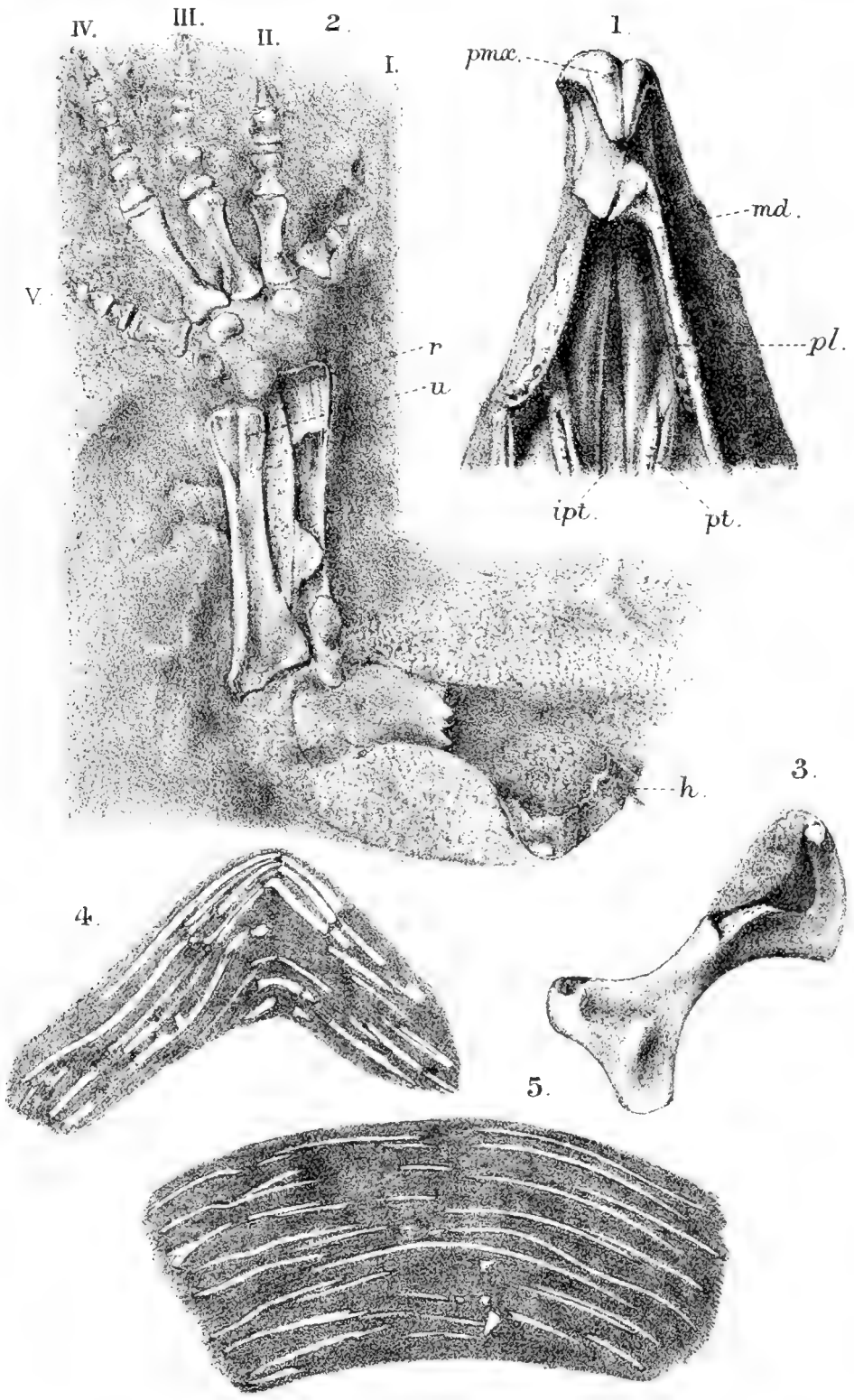
maxilla is a stout, deep, and smooth laminar bone, but its thin oral border has not hitherto been sufficiently well seen to determine whether or not it was toothed. The palate (Plate II., fig. 1) is only partially known from the two specimens in the British Museum noticed by Huxley (4). The pterygoids (*pt.*) are long and narrow stout bars, each evidently extending outwards behind in a deep lamina for union with the quadrate, and apposed to the basi-ptyergoid process of the basi-sphenoid with a relatively large wing. A pair of short longitudinal ridges, which extend along the bone immediately in front of the last-mentioned wing, seem to bear stumpy teeth. The interptyergoid vacuity (*ipt.*) is very long and narrow, extending further forwards than in *Sphenodon*. The palatine (*pl.*) is also long and narrow, forming a single sharp longitudinal ridge, which bears one row of stumpy teeth, evidently opposed to the inner side of the mandibular dentition. The vomerine region is unknown.

The mandible is best shown in the specimens described by Owen (S. Nos. 1, 3). It is peculiar in exhibiting no prominent coronoid process, and there is no lateral vacuity. The symphysis is short and bluntly pointed, only the extreme end being in contact with the downwardly curved beak. The splenial enters the symphysis and is conspicuous when viewed from below, where it forms the lower edge of the anterior part of each mandibular ramus. The dentary bears a single row of stumpy teeth, as imperfectly shown in B.M. No. R. 1236. The surangular (named coronoid by Owen) is relatively large, but scarcely rises higher than the posterior end of the dentary. The hinder end of the articular, posterior to the glenoid cavity for the upper jaw, has not been clearly observed.

Vertebral Column.—The vertebræ are so delicate and fragile that they are rarely well preserved. All are characterised by a very large neural canal and also by a comparatively small, elongated and constricted centrum, which is deeply concave at each end. No intercentra have been observed even in specimens which seem to be sufficiently clear to show them if these elements were present. The number of vertebræ is uncertain in all regions, but in S. No. 3 there is space for seven or eight cervicals, while in B.M. Nos. R. 1538–39 there seems to be evidence of about 15 rib-bearing trunk vertebræ. The neural spines in the latter are less elevated than in *Sphenodon*, but not thickened at their upper end. There are remains apparently of long posterior cervical ribs in B.M. No. R. 1239; while the trunk-ribs are large, stout, antero-posteriorly compressed, marked by a longitudinal groove on each face, and clearly single-headed (S. No. 4). There are no traces of uncinatè processes. The sacrum has not been satisfactorily observed, and only a few of the anterior caudal vertebræ are known (Huxley, 4). As in *Sphenodon*, the neural spines in the anterior caudals are comparatively long and slender, while the chevrons are still longer.

Fore Limb.—In the pectoral arch the median limb of the interclavicle is relatively long, as in *Sphenodon*; but the coracoids seem to have been completely ossified, not remaining cartilaginous at the inner border as in the existing genus. Each coracoid is somewhat longer than broad, and a fragmentary example has been figured by Huxley (4, pl. xxvii., fig. 3), who marks a remnant of the anterior border '*cl.*' but leaves the determination of this piece doubtful. A crushed specimen of the bone was also identified by Owen (1, pl. vi., fig. 9), but he did not recognise the usual oval foramen, which is exhibited in all the three known coracoids internal





J. Green del et lith.

RHYNCHOSAURUS ARTICEPS.

Illustrating the Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

to the front part of the glenoid articulation for the humerus. The scapula is still represented only by the specimen described by Owen (1, pl. vi., fig. 8), and by an imperfect example in S. No. 4. It is expanded and shaped nearly as in *Sphenodon*, but somewhat shorter and broader, and, like the coracoid, more extensively ossified than the corresponding element in the existing genus under comparison. The 'moderately long trihedral process given off from the convex margin near the articular end' of this bone, described and figured by Owen, does not exist, but depends on the misinterpretation of a fragmentary part of the fossil. There is very little space for a sternum, the abdominal ribs approaching the interclavical more closely than in *Sphenodon*. The humerus (Plate II., figs. 2, 3), already noticed by Owen (1, 3) and Huxley (4), is relatively shorter and broader than in *Sphenodon* but twisted to the same extent. All the known specimens are incomplete, but two are sufficiently well preserved at the lower end to show that there is no epicondylar foramen. The radius and ulna are not quite so long as the humerus, and are better shown in the original of Plate II., fig. 2, than in any specimen hitherto described. The ulna (*u*) is the stouter bone, with a marked triangular expansion at the upper end, but a smaller olecranon process than in *Sphenodon*. The radius (*r*), which is only slightly expanded at each end, extends further down into the carpal region than the ulna. The carpus seems to have been less ossified than in the existing *Sphenodon*, and is represented chiefly by a vacant space in the fossil. In Plate II., fig. 2, an obscure trace of an intermedium is seen, separating the lower ends of the radius and ulna less widely than in *Sphenodon*. There are also traces of the ossified ulnare and carpalia Nos. 2 and 4. Indications of the same ossified carpal elements are also observable in S. No. 4. The five digits of the fore foot are comparatively stout, and the fifth is relatively much shorter than in *Sphenodon*. The phalangeal formula is clearly 2, 3, 4, 5, 3, and the terminal phalanges must have formed slender pointed claws.

Hind Limb.—The hind limb is larger than the fore limb, its relative proportions being indicated in the accompanying text-figure. As shown in the imperfect skeleton described by Huxley (4 pl. xxvii., fig. 4), the pelvis is characterised by the great expansion of the ischia and the consequent reduction in size of the obturator foramen. These bones are only represented by impressions in the specimen mentioned, and they are evidently crushed, so that their precise form and relations are uncertain. The ilium is incompletely known, but a fragmentary specimen is noticed by Owen (1, pl. vi., fig. 10) in a fossil which I have not found in the Shrewsbury collection. The bone is also partly exhibited in S. No. 5, in which appearances suggest that the ilium met the ischium and pubis in a closed acetabulum. The femur, tibia, and fibula are shown by B.M. No. R. 1239 to have had an internal cavity, but they are not well-preserved in any known specimen. The femur is sigmoidally bent to about the same extent as that of a crocodile, and its length somewhat exceeds that of the tibia and fibula. The precise shape of the tibia is unknown, but the fibula is equally expanded at each end, and as widely separated from the tibia as in *Sphenodon*. The tarsus must have been considerably ossified, but its elements are confused in the fossils, and their identification is uncertain. The foot is only known by the two incomplete specimens described by Huxley (4, pl. xxvii., figs. 4, 5). It is long and narrow, with the five toes ending in small pointed claws; but it is relatively shorter than in *Sphenodon*. Both the metatarsals and the phalanges are relatively

broad and depressed, but the phalangeal formula is clearly 2, 3, 4, 5, 4, as in *Sphenodon*. Metatarsal I. is remarkably short and broad, and the extremity of its toe scarcely reaches beyond the distal end of the metatarsal of the next toe, being shorter than in the existing genus. Metatarsal IV. is much the largest, but its length equals only half that of the fibula, whereas in *Sphenodon* the same bone is nearly two-thirds as long as the fibula. Metatarsal V. is curiously modified and displaced upwards, as in *Sphenodon* and the *Lacertilia*; but the distal end of its toe only reaches just beyond the distal end of metatarsal IV., whereas the corresponding toe of *Sphenodon* reaches the end of the first phalangeal of toe IV.

Plastron.—The plastron of abdominal ribs is at least as extensive as in *Sphenodon*, and its shape seems to indicate that the body was relatively broader in *Rhynchosaurus* than in this existing genus. The abdominal ribs are very slender, arranged in three longitudinal series, and well seen both in B.M. No. R. 1238 and S. No. 5. The anterior rows just behind the pectoral arch are not thicker than the others, but their middle piece is sharply bent, so that its two arms are inclined to each other in the median line at about a right angle (Plate II., fig. 4). This angulation gradually disappears in the middle pieces of the hinder abdominal ribs, which are only gently arched (Plate II., fig. 5).

Skin.—The dermal covering of *Rhynchosaurus* has already been noticed by Burckhardt (5) and the present writer (6), and is especially well shown on part of the fore limb represented in Plate II., fig. 2. It is indicated in the fossils merely by an impression, without any trace of calcified matter; and it is most probably to be interpreted as an armature of horny scales. It is seen in the fossils in the region of the ribs, below the root of the tail, and on the fore limb, so probably covered the whole animal. The scales are very small and irregularly rhombic or polygonal in shape, each with a slightly elevated central boss. In one specimen Burckhardt interprets the markings to mean that on the hinder part of the back the scales are much larger and flatter than those of the flank; but this determination is somewhat uncertain.

Conclusion.—The general result of these new observations on *Rhynchosaurus* is to confirm previous statements as to the resemblances and differences between this Triassic reptile and the existing *Sphenodon*. It is obviously a typical Rhynchocephalian, and is more specialised in several respects than its surviving representative. It resembles many very ancient reptiles, however, in the relatively great expansion of its ossified coracoids and pubes, and in the small size of the obturator foramen in the pelvis. It also appears to be noteworthy for the relatively small space available for a cartilaginous sternum. The condition of the pectoral and pelvic arches, however, may have been partly correlated with an aquatic mode of life; for there cannot be much doubt that *Rhynchosaurus* was more amphibious in habit than *Sphenodon*. The everted rims to the upturned eyes, the sigmoidally bent femur, and the broad flattened phalanges of the hind foot all suggest life in water.

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3. R. OWEN.—'Notice of a Skull and parts of the Skeleton of *Rhynchosaurus articeps*,' Phil. Trans. 1862, pp. 466, 467, pl. xxv.

4. T. H. HUXLEY.—'Further Observations upon *Hyperodapedon gordonii*,' Quart. Journ. Geol. Soc. vol. xliii. (1887), pp. 689-692, pl. xxvii.

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6. A. S. WOODWARD.—'Notes on Footprints from the Keuper of South Staffordshire,' Geol. Mag. [4] vol. ix. (1902), pp. 215-217, text-figs. 1, 2.

Explanation of Plate II.

Rhynchosaurus articeps, Owen; Keuper Sandstone, Grinsill, Shropshire. All figs. nat. size.

Fig. 1. Palatal view of skull (B.M. No. R. 1236): *ipt.*, interpterygoid vacuity; *md.*, mandible; *pl.*, palatine; *pmx.*, premaxilla; *pt.*, pterygoid.

Fig. 2. Left fore limb, anterior aspect, with traces of integument (S. No. 6); *h.*, humerus; *r.*, radius; *u.*, ulna; I-V., digits.

Fig. 3. Right humerus, dorsal aspect (B.M. No. R. 1239).

Fig. 4. Anterior abdominal ribs (B.M. No. R. 1238).

Fig. 5. Posterior abdominal ribs (S. No. 5).

Report on Footprints from the Trias. Part IV. By H. C. BEASLEY.

Since the last Report (1905) some further forms have been examined, and may be now described.

Cheirotheroid Form.—A 4. Pes: resembles that of A 1 (Report 1903), but somewhat more slender and of smaller size, being only 7 inches in length. The nails well shown and sharply pointed. The sole covered with flattened tubercles 1 to 2 mm. in diameter.

Manus: Length, 4 cm.; breadth, 4.5 cm. Four digits shown: III. the longest, 2.5 cm.; II. slightly shorter, each tapering very rapidly and evenly to a sharp termination, though no trace of a nail has been noticed; width of each of these digits about 1 cm. at root. The outer digits, presumably I. and IV., are much shorter, about 8 mm. So far no trace of V. has been seen. The surface of the natural cast is well rounded from before backwards, and transversely.



Manus. $\frac{1}{2}$ nat. size.

The distinguishing feature of this form is the small size of the Manus as compared with the Pes—viz., about one-seventh the length. Also the greater parallelism of the digits, giving it a more compact appearance.

Numerous prints have been seen amongst those lately raised at Storeton. There is also an example in the Liverpool Museum, 'no locality.'

A fine series is shown on a large slab (6 feet square) at Storeton, crossing it diagonally. The prints have the same linear arrangement noticed in A 1 (see Report, 1903). Distance from one footprint to the next of same foot, 2' 9" against 3' 7" in A 1. Manus is shown $\frac{3}{4}$ inch in advance of extremity of III. digit of Pes.

This form may be compared with the smaller prints on the British Museum slab R. 729, described and figured as 'L' in Part I. of this Report (1903).¹

¹ Material obtained since this report was in type will necessitate some modification of the description of A. 4 in the next Report of the Committee.

It is just possible that the difference between the two forms in the number of digits leaving impressions may be due to age.

Rhynchosauroid Form.—D. 6. This was referred to in last Report (1905) as occurring on some slabs from Shrewley in the Warwick Museum, which contains numerous examples. No others have been seen since.



Manus and Pes.
 $\frac{1}{2}$ nat. size.

Pes: Five digits shown; IV. longest. They decrease rapidly in length from IV. to I., which is very short. Only a trace of V. has been observed. They are fairly evenly divergent, and often curved inwards (towards I.). In all these respects they resemble D 1. The form of the digits differs from it. They increase in width gradually towards the extremities, which are bluntly rounded off, and the presence of nails is very

uncertain. The length of IV., the longest, is 3.5 cm. There is no palmar surface.

Manus: Similar to Pes, but only two-thirds the length. The print of V. has not been noted at present, but the similarity to the Pes leaves little doubt as to its actual presence. The print of the Manus is just in front of that of the Pes, the proximal end of IV. being in contact with II. of Pes.

All the examples seen are from the Upper Keuper sandstone of Shrewley, Warwickshire.

A form that comes into neither of the three larger groups has been occasionally found, and was described in 'Proc. Liv. Geol. Soc.,' 1895-6, under letter C.

C. Five digits; the middle one (III.) the longest, being one-half the total length of print; II. and IV. rather shorter; I. and V. very small, and V. more divergent than the rest and rather in their rear. Digits very broad, not less than half their length; they do not taper at all, and are rounded at the extremity, without a trace of a nail; II., III., and IV. lie close together and parallel; the palmar surface is about one-half the print.



$\frac{1}{2}$ nat. size.

Whether this represents the Pes or the Manus is not known, nor have any but isolated prints been seen, so that the numeration of the digits is not absolutely certain.

The longest digit being the middle one would seem to connect this with the Cheirotheroid form, but there is no other connecting feature. There is a possibility that it may be the Manus of some small Cheirotheroid form, but it is very doubtful.

The prints vary considerably in size, one from Storeton measuring 28 mm. and one from Runcorn 16 mm. in length.

A form of somewhat similar proportions, and in size about equal to that of the smaller specimen, is in the Grosvenor Museum, Chester. It was obtained by Mr. R. Newstead, F.L.S., from a small quarry in the Waterstones (or possibly the Upper Keuper) at Eddisbury. It differs from that just described in the digits tapering rapidly to a sharp point. The foot appears to have slipped slightly, and therefore the print is imperfect, which will account for there being no trace of V. digit.

During the visit of the North Staffordshire Field Club and the Liverpool Geological Society to Hollington, Staffordshire, in April last, some footprints differing from any of those previously described were seen,



Slab from Hollington, Staffordshire, with tracks of footprints (type O).

*Illustrating the Report on the Investigation of the Fauna and Flora of the
Trias of the British Isles.*



They were from Mr. J. Fielding's quarry, adjoining the workings in which the bones of *Hyperodapedon*¹ were found. The beds are in the Lower Keuper Sandstone, and must have been formed under conditions quite similar to those yielding footprints in Cheshire. Both Rhynchosauroid and Cheirotheroid prints are frequent. This print does not, however, fall readily into either of these classes; it therefore seems advisable to give it a distinctive letter.

O 1. A five-toed form, the three middle toes strongly impressed; they are joined at the base and widely divergent, and are of nearly equal length, about 35 mm. in the examples seen. They are very slender, and taper evenly to the extremity, ending in a sharp nail. There is a trace of a ball or pad in their rear. On each side a very short digit (I. and V.) projects at about right angles to the axis of the foot, in some cases even inclining backwards. There is no doubt as to the presence of these digits, though they are so slightly marked that at first sight the print resembles the three-toed prints from the Connecticut Valley.



$\frac{1}{2}$ nat. size.

There is a slight trace of what may be the *Manus*, but it is too imperfect for description.

It is hoped that further more perfect specimens may shortly be found, now that those on the spot are on the alert. I should like to record the obligation geologists are under to Mr. Fielding for the facilities he has so readily given for research in all his quarries.

The slab [Plate III.] which is a strongly ripple-marked flaggy sandstone, was secured from the North Staffordshire Field Club, and is at present in the Hanley Museum.

Erratum.—Report for 1905, p. 167, lines 22 and 24: for 'Giboni' and 'Gibon,' read 'Gihoni' and 'Gihon.'

Composition and Origin of the Crystalline Rocks of Anglesey.—Report of the Committee, consisting of Mr. A. HARKER (Chairman), Mr. E. GREENLY (Secretary), Mr. J. LOMAS, and Dr. C. A. MATLEY, appointed to enable Mr. E. Greenly to complete his Researches thereon.

THE work for which this Committee was appointed is proceeding, and in presenting this Interim Report the Committee ask to be reappointed, with the addition of Professor Orton. The laboratory generously equipped by the University College of North Wales for the special purpose of Anglesey petro-chemical research, was in September 1905 put into the charge of Mr. John Owen Hughes, B.Sc., a senior student of the College.

In January, however, Mr. Hughes was appointed Junior Demonstrator in Chemistry, and his time thereby restricted and the rate of progress diminished.

The problem selected for attack at the outset was that of the origin of the hornfels and other metamorphic rocks associated with the Plutonic Complex of the heart of the Island, a subject on which widely divergent views have hitherto prevailed. This research is still going on. When it

¹ Now in the British Museum.

is completed, it is proposed to investigate the jaspers and the very remarkable pillowy igneous rocks with which they are associated; while later the origin of widespread types of regional metamorphism will claim attention. Some exceptional rocks have already been discovered, particularly a graphitic schist, and a remarkable manganese limestone.

Life-zones in the British Carboniferous Rocks.—Interim Report of the Committee, consisting of Dr. J. E. MARR (Chairman), Dr. WHEELTON HIND (Secretary), Dr. F. A. BATHER, Mr. G. C. CRICK, Dr. A. H. FOORD, Mr. H. FOX, Professor E. J. GARWOOD, Dr. G. J. HINDE, Professor P. F. KENDALL, Mr. R. KIDSTON, Mr. G. W. LAMPLUGH, Professor G. A. LEBOUR, Mr. B. N. PEACH, Mr. A. STRAHAN, Dr. A. VAUGHAN, and Dr. H. WOODWARD. (Drawn up by the Secretary.)

THE last twelve months have seen much important work done in various Carboniferous areas.

Mr. H. Bolton regrets that the report of the collecting done in the lowest measures of the Bristol coalfield is not yet in readiness for inclusion in this report, but it is hoped that the results will be published at an early date.

This year the gentleman who undertook the work of collecting in the Upper Nidd Valley, where sections were being excavated in connection with the Bradford Corporation Waterworks, the object being to show the relation of the 'shell bed' in the Millstone Grit and the *Dibunophyllum* beds of the Carboniferous Limestone Series, unfortunately failed to make any collections, and no results have been obtained beyond seven measured sections.

As mentioned in the last report, work was done by Mr. J. T. Stobbs, F.G.S., round Holywell in North Wales. I joined him on two occasions later on in the year, and we carried on our investigations of the Carboniferous Limestone Series and the beds which succeed them from Holywell in the North to Llanymynech in Shropshire, and as far west as Llysyaen and Llandulas. We published the results of our work in a paper read before the Geological Society on April 4.

We acknowledge with thanks the kind assistance of Dr. A. Vaughan, Dr. Smith Woodward, and Mr. Kidston in the determination of corals, brachiopods, fish remains, and plants.

Certain very important facts resulted from the comparison of the faunas, found at different horizons in North Wales, with similar assemblages of fossils in the Bristol area.

The lowest beds of the Carboniferous Series in North Wales are the Basement beds, an irregular deposit of varying thickness, absent in many places, and where present containing only derived fossils. These beds consist of conglomerate and dark red shales, and lie unconformably on the upturned edges of the Ordovician and Silurian rocks. At Minera, however, the lowest limestones lie on the upturned edges of the Bala Series, and the red Basement beds are absent. They contain *Daviesiella llangollensis* and are a calcareous conglomerate.

The thickest and best section of Basement beds is at Ffernant Dingle, near Llysyaen.

In the limestones which immediately succeed the Basement beds the chief fossils of importance are *Daviesiella llangollensis*, and *Seminula* aff. *ficoidea*. The former characterises the lowest limestones, and for North Wales is a very satisfactory zonal index. *Seminula* aff. *ficoidea* is important because it enables us to correlate the beds with the Bristol area. Only some very few feet of rocks contain this fossil, but we got it at Llysvaen and at the base of Moel Hiraddug, in a small quarry between Pentre Cwm and Pentre Bach. Here we obtained plant remains, amongst which Mr. Kidston recognised *Archæosigillaria Vanuxemi*, Söpp. In Great Britain this plant hitherto was only known to occur in the Carboniferous Limestone near Shap Toll Bar.

The presence of only a few feet of beds containing *Seminula* aff. *ficoidea* at once fixes the horizon of the lowest limestones of North Wales as the top of the *Upper Seminula* zone and base of the lower *Dibunophyllum*, and unmistakably demonstrates the absence of all the zones of the Bristol sequence below. Consequently in North Wales there are no representatives of the Tournaisian, or Lower Carboniferous. We also learn that the North Wales area was not submerged till late on in Carboniferous Limestone times, and that the Basement beds are probably of Upper *Seminula* age.

Above the *Seminula* beds are a series of limestones with *Cyathophyllum Murchisoni*, *Dibunophyllum*, ϕ , and a number of species of Brachiopoda highly suggestive of the Lower *Dibunophyllum* zone.

This zone we were able to trace south to Llangollen, and thence on to Porth y Waen, near Llanymynech.

Higher up in the Limestone Series is a very rich Upper *Dibunophyllum* zone in which all the corals occur, which Dr. Vaughan regards as typical of that zone at Bristol. The characteristic forms are *Dibunophyllum*, ψ , *Lonsdaleia floriformis*, *L. rugosa*, *Lithostrotion junceum*, *L. irregulare*, *Cyathophyllum regium*, *Phillipsastrea radiata*, *Campophyllum Murchisoni*. In this zone *Productus giganteus* and its variant and allied forms occur in profusion and in some localities, Waenbrodwas, Llangollen, a rich and varied brachiopod fauna is also present.

We were able to mark off at the top of the Upper *Dibunophyllum* zone certain beds which contained the corals *Amplexi-zaphrentis* and *Cyathaxonia*, and which we wished to denote as a sub-zone of the Upper *Dibunophyllum*. We do this because we have noted the occurrence of this zone immediately underlying the base of the Pendleside Series in North Staffordshire and throughout the Craven and Bolland districts in Yorkshire. At Whitewell the shales which immediately succeed the Carboniferous Limestone are crammed with these corals, and at the Cracoe Knolls, beds with these corals are seen to intervene between the *Posidonomya* beds of the Pendleside Series and the Upper *Dibunophyllum* zone of the limestones. This sequence is seen in a little stream south-east of the hill called Skelterton.

In North Wales in certain localities the colour of the limestones and their lithological character vary considerably, and the abundance of fossils is very variable.

Locally certain dark limestones in the Upper *Dibunophyllum* zone are known as Aberdo limestones, and were once extensively worked for hydraulic cement.

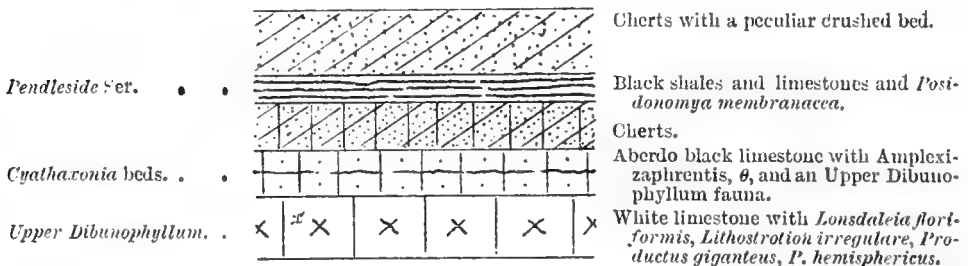
Higher up occurs another series of black limestones, but lithologically the two series are vastly different in fracture and composition; but more

important still the upper series of black limestones contain a totally different fauna and flora from the lower series.

The two series have unfortunately been mistaken owing to insufficient attention being paid to the fauna, and in places have been mapped as occurring on the same horizon. The mistake is unfortunate, because the junction of the Upper and Lower Carboniferous beds occurs at this point, and it is of the utmost importance that the junction should be accurately mapped. I therefore propose to go into the matter here in some little detail; and this is the more necessary because within a few miles certain very definite changes of lithological character set in apparently on the same horizon.

Commencing in the eastern part of the area, a little east of Holywell, on the road from Brynford, the upper beds of the Carboniferous Limestone are seen to be succeeded by cherts, which in turn are succeeded by the black shaley limestones of the Holywell shales, containing a Pendleside fauna and flora; that is to say, a Pendleside fauna succeeds the cherts.

Further west, at the Grange Quarry, a series of sections show



The black shales at Holloway, which are apparently intercalated between two series of cherts, contain *Posidonomya membranacea*, M'Coy, and *Acrolepis Hopkinsi*, M'Coy, both of which species are typical of the Pendleside series, and have never been found in beds below.

At Treloggan, about four miles N.W., quarries show a similar succession. Here there appear to be two cherty series with some black shales between them.

Three miles N.W. are the chert quarries of Pentre, near Gronant. The cherts here are finely bedded, and there is a face of 70 feet. In the cherts we obtained—

P. longispinus. *P. punctatus*. *P.* sp., a spinose form.

The cherts are succeeded by fissile shales, which are also seen in the road by some cottages some half-mile east, dipping off the cherts beds near Talacre. The shales at Pentre contained *Posidonomya Becheri* (rare here), *Acrolepis Hopkinsi*, *Cladodus* (teeth), and plant remains.

Here, too, at any rate, a Pendleside fauna succeeds the cherts.

Some isolated exposures of cherts are seen nearly a mile further west, south of the main road to Prestatyn; but here the beds are thin and yellowish and much tilted, and we have no evidence of their relation to beds above or below them. Up to this point the succession seems to be Pendleside Series, cherts, and Cyathaxonia beds.

The Teilia section demonstrates that the Pendleside Series lie directly and apparently conformably on the Cyathaxonia limestones.

The Teilia Quarry contains the following fauna and flora :—

<i>Posidonomya Becheri.</i>	<i>Glyphioceras reticulatum.</i>
<i>Posidoniella levis.</i>	? <i>Prolecanites compressus.</i>
<i>Pterinopecten papyraceus.</i>	<i>Orthoceras</i> sp.
„ <i>carbonarius.</i>	<i>Rhynchonella</i> aff. <i>trilatera.</i>
<i>Adiantites antiquus.</i>	<i>Sphenopteris affinis.</i>
<i>Sphenopteris Teiliana.</i>	<i>Rachopteris glabellata.</i>
„ <i>subgeniculata.</i>	„ <i>inequilatera.</i>
„ <i>striata.</i>	? <i>Archeopteris</i> sp.
„ <i>pachyrachis.</i>	<i>Asterocalamites scrobiculatus.</i>
„ var. <i>stenophylla.</i>	<i>Lepidophloios</i> sp.
„ <i>Schlebaui.</i>	

Here, apparently, without unconformity, the *Cyathaxonia* beds are immediately succeeded by the Pendleside Limestones without any cherty series, and the Teilia Limestones here are more calcareous and contain less carbonaceous matter than the Holywell shales further east.

Traced northwards towards Prestatyn we find *Posidonomya Becheri* beds succeeding the *Cyathaxonia* beds of Prestatyn, which are white in colour and not at all like the 'Aberdo' limestones of Treloggan or Grange Quarry; but the fossils indicate very markedly their real horizon and homotaxis.

At Prestatyn the series is as follows :—

1. Pendleside limestones, about 70 feet thick, with *P. Becheri* and *Pterinopecten papyraceus*.

At the base :—

2. *Cyathaxonia* beds with *P. giganteus*. Practically free from chert or siliceous replacement.

3. A series of black limestones then bedded and not very fossiliferous.

With *Zaphrentis* aff. *cnniskilleni*, *Campophyllum Derbyense*, *Productus longispinus*, *Martinia glabra*.

These black limestones cannot be the equivalents of the Teilia limestones, but are far below them. They probably belong to the lower part of the Upper Dibunophyllum zone. The most striking point at Teilia and Prestatyn is the absence of the thick chert series, so well developed, only one mile to the east.

Another fine exposure of the *Posidonomya* beds is at Lady McLaren's quarry. The lower beds are rich in fossils, the most common being *Pterinopecten papyraceus*, but some plants similar to those which were found at Teilia occur here. The very lowest bed exposed contains *Cyathaxonia* and *Amplexi-zaphrentis*. A few yards west the *Cyathaxonia* beds are seen in another quarry, demonstrating that the same succession occurs here that obtains on the other side of the hill at Gwaerysgor and Teilia. Walking east from Lady McLaren's quarry outcrops of the *Posidonomya* beds occur at intervals as far as Top Nant Farm. East of the farm is a shallow sinking, from which *Posidonomya* limestones have been got; higher up the hill a shallow cutting shows smashed chert debris, making it appear that here some cherts lie above some of the *Posidonomya* limestones; but the junction is not seen, and the idea that the pits have been trials for lead along a fault is not impossible. About a quarter of a mile north is a quarry in chert at about 200 feet above O.D., the chert E. of Top Hant Farm being 450 feet above O.D.

The general dip being N.E., trials for lead along the lower part of the hill and elsewhere point to faults which have not been mapped. We know that at the Grange Quarry, Holloway, and Treloggan the cherts rest on the *Cyathaxonia* beds, and the question is to what conditions the absence of chert immediately above the *Cyathaxonia* beds at Prestatyn, McLaren's Quarry, and at Teilia are due.

Two solutions at least are probable.

One, that the cherts at Holloway and Treloggan and Pentre are the equivalents of the lower portion of the Teilia limestones, the CaCO_3 having been replaced by SiO_2 .

In favour of this view the following facts may be advanced :—

1. The position of the cherts and *Posidonomya* beds with regard to the *Cyathaxonia* beds.

2. The thin-bedded and finely stratified character of the *Posidonomya* limestones and the cherts.

3. At the Grange Quarry shales and thin black limestones occur in the cherts with a Pendleside fauna.

4. The Pendleside Series at Teilia and Prestatyn is more calcareous and contains much less carbonaceous matter than the series known as the Holywell Shales.

On the other hand, the fossils that have been obtained in the cherts, few though they are, have not a Pendleside facies, especially the fauna obtained from the cherts of Pentre Halkin, which succeed the *Cyathaxonia* beds of Waenbrodilas, about three miles south of Holywell.

Waenbrodilas Quarry shows the Upper Dibunophyllum beds and *Cyathaxonia* beds succeeded by from 70 to 100 feet of cherts. In the upper part of these cherts several fish teeth occur which have an Upper Dibunophyllum facies rather than a Pendleside.

Dr. Smith Woodward recognised a *Cochlodont* tooth and a specimen of the tooth of *Deltoptychius*.

Several brachiopods are present, amongst which are *Spiriferina biplicata* and *Dialasma ficus*, *Productus scabriculus*, *P. aff. laxispina*, all of which Dr. Vaughan has determined. The cherts are often crinoidal, more so than any bed of the Pendleside Series.

The *Cyathaxonia* limestones and the Upper Dibunophyllum beds at Waenbrodilas and elsewhere on Halkin Mountain are very cherty and contain a large percentage of SiO_2 . It is therefore quite certain that the replacement of silica at this horizon was very local, because these beds at Holywell, The Grange, Treloggan, Prestatyn, and Gwaenysgor are practically free from it.

It may be, therefore, that at the Grange Quarry and Treloggan the lowest beds of the Pendleside Series have the CaCO_3 replaced by SiO_2 , while nearer Prestatyn and Teilia only beds somewhat higher in the series have undergone this chemical change. In connection with this view the great variation in the thickness of chert must be remembered.

The other explanation is that the chert beds have been cut out at Teilia and Lady McLaren's Quarry by unconformity or by faulting. The ground is difficult; faults are numerous and difficult to trace owing to the amount of drift and paucity of sections.

In favour of this view is the fact that *Posidonomya Becheri* and the other fossils which occur with it at Teilia and Prestatyn have never been found in the cherts.

There can be no doubt that the Pendleside Series is well represented in North Wales, and includes the Teilia limestones and the series of Lady McLaren's Quarry, and the black shales and limestones known as the Holywell Shales. Possibly the latter are somewhat higher in the series than the Teilia beds. The fauna of the Holywell Shales is fairly rich and contains :—

Posidonomya Becheri.	Orthoceras sp.
„ membranacea.	Glyphioceras reticulatum.
Pterinopecten papyraceus.	„ Phillipsii.
„ carbonarius.	„ diadema.
Actinopteria persulcata.	Productus cora (late mutation)
Leiopteria, cf. longirostris.	Lingula mytiloides.
Posidonomya minor.	Reed-like plant remains.
„ levis.	

These beds are well exposed in the quarry E. of Holywell, above the workhouse, and there is a good section in the dingle between Holywell and the Bagillt Road, and also in that road.

These black shales, which form the upper part of the Pendleside Series of North Wales, are known as the Holywell Shales. They were unfortunately mapped and correlated with the Lower Coal Measures of Lancashire ; a mistake indicated at once by a study of the fauna and the absolutely different lithological characters of both series and the negative evidence afforded by the absence of the characteristic Coal Measure fauna.

Succeeding the Holywell Shales are a thick series of sandy shales and the Gwespyr Sandstone, which we estimate to be about 300 feet thick.

This series we provisionally correlated with the Millstone Grit Series on account of its position. The sandstone is fine-grained and contains numerous fragments of plant remains. It also contains a good deal of felspar.

We therefore classify the Carboniferous succession of North Wales as follows :—

Coal Measures	C.M.
Millstone Grit	M.G.
Pendleside Series	P.
Cyathaxonia beds	D ₃
Upper Dibunophyllum beds	D ₂
Lower Dibunophyllum beds	D ₁
Seminula beds, a few feet	} S ₂
Basement beds	

Excellent work has been done by Mr. T. F. Sibly on the Carboniferous limestone of Weston-super-Mare and the Mendip area. His papers have both been published in the 'Quar. Jour. Geol. Soc.' He has found it possible to carry on the subdivisions proposed by Dr. A. Vaughan for the Bristol area and to demonstrate the occurrence of each zone and sub-zone in the districts he describes. Naturally in examining new areas some fresh details have come to light, but the extension of Dr. Vaughan's lines is very important.

Dr. Vaughan himself has demonstrated that his zones can be traced throughout South Wales ; consequently we may now consider that the south-west Carboniferous province has been accurately zoned. In conjunction with Dr. Matley he has shown that the Carboniferous succession at Rush contains the whole of the zones which range from the Upper

Zaphrentis to the Upper Dibunophyllum zone (*Cyathaxonia* sub-zone). It is interesting to note that he in Ireland and we in North Wales have demonstrated a sub-zone at the top of D₂.

It is important to note that he recognises a true Zaphrentis, *Z. aff. enniskilleni*, as present in the Upper Dibunophyllum zone. We have obtained this coral in the black limestone west of Prestatyn at this horizon, and Dr. Vaughan has obtained it at Oystermouth, Glamorganshire. It also occurs in the Black Limestone of Ashford, Derbyshire.

Passing to Yorkshire, Mr. Cosmo Johns, at my suggestion, kindly examined the coral fauna of the Basement conglomerate in the neighbourhood of Ingleboro'. The beds contain several corals and more rarely brachiopods. The fossils have been submitted to Dr. Vaughan, who suggests the horizon to be the base of the Seminula zone and upper part of the Syringothyris zone that is somewhere about the horizon of the *Michilinia megastoma* beds of Rush. This correlation is of great interest, because it is estimated that the whole of the Limestone Series in the neighbourhood of Ingleboro', including the Yoredales, is only 1,500 feet, and the Dibunophyllum fauna as found in rocks is probably here considerably more than 1,200 feet thick. An interesting problem presents itself as to what happened in this area between Lower Seminula and Lower Dibunophyllum times. I hope that some work on which I am engaged on the Carboniferous succession of the Isle of Man may throw some light on this question. In Derby Haven *Michilinia megastoma* occurs in abundance in limestones which succeed the Basement conglomerate, and this may give a clue. I should not be surprised if these beds eventually turn out to be in the Dibunophyllum zone.

Important work has to be done in the north to work out the exact zone of each Basement bed. For example, in the neighbourhood of Shap and Askham, bordering the Lake District, the lowest limestones contain a well marked Dibunophyllum fauna, pointing to the existence of land in the Lake District in Upper Carboniferous Limestone times. Nowhere that I know at present has a fauna below D₁ been obtained in the Pennine area south of Northumberland. The corals of the Lower Limestone Series of the West of Scotland are undoubtedly of Upper Dibunophyllum age, and the exact results of this fact have to be worked out.

The result of Mr. Tai's collecting last year in Northumberland is expressed in the following table.

The object of his research was to endeavour to ascertain the fauna which characterises the horizon of the Fell Top Limestone, what may be regarded as the top of the Carboniferous Limestone Series in that area. The thin limestone is succeeded by the Millstone grits of that district.

The general results show that the fauna has a Dibunophyllum facies, but that he did not get any of the corals which in the Midlands we now recognise as zone indices of the top beds—*Cyathaxonia* and *Amplexi-zaphrentis*.

I append notes by Dr. Vaughan on the corals, which were exceedingly common where they were found.

The list of localities is as follows :—

1. Sheet 106. S.E.	Lat. 54° 59' 30''	} Stream $\frac{1}{4}$ mile S.E. of Acomb.
	Long. 2° 6'	
" "	Lat. 54° 58' 45''	} Darden Burn $\frac{1}{2}$ m. S.S.W. of Coastley Shale with limestone nodules above a 2-foot limestone, which is dark, with small crinoid ossicles and a 4-in. coal below it.
" "	Long. 2° 9' 50''	

3.	Sheet 106.	S.E.	Lat. 54° 55' 40'' Long. 2° 4' 30''	} Right bank of Devil's Water, $\frac{1}{4}$ mile E. of Ordley, 3 miles S.S.E. of Hexham. Calc. shale with limestone bands 6 feet. Dark limestone (small crinoids), D/2 ft. White sandy free clay.
4.	"	"	Lat. 54° 55' 20'' Long. 2° 9'	
5.	"	"	Lat. 54° 50' 40'' Long. 2° 13' 50''	} Stream $\frac{2}{3}$ m. E. of Sipton Shield, $3\frac{1}{2}$ miles S.S.E. of Allendale Town. Three limestone bands in a series of calcareous sandstones.
6.	"	"	Lat. 54° 50' 50'' Long. 2° 13' 40''	
7.	"	"	Lat. 54° 51' 35'' Long. 2° 10' 25''	} Streams between Hangman Hill and Pike-rigg, 4 m. S.E. of Allendale Town.
8.	"	"	Lat. 54° 51' Long. 2° 10' 35''	
9.	Sheet 102.	N.E.	Lat. 54° 49' 10'' Long. 2° 10' 45''	} Near source of stream Heathery Burn Moor, nearly 2 m. N.E. of Allenheads.
10.	"	"	Lat. 54° 40' 40'' Long. 2° 5' 45''	
11.	"	"	Lat. 54° 49' 10'' Long. 2° 2' 50''	} Burnhope, S.E. of Sandyford.
12.	"	"	Lat. 54° 46' 30'' Long. 2° 12' 40''	
13.	"	"	Lat. 54° 46' 10'' Long. 2° 13'	} 25-30 feet above Little Limestone, in stream $\frac{3}{4}$ m. N.N.E. of Burtree Ford, $11\frac{2}{3}$ miles N. of bridge at Wearhead.
14.	Sheet 106.	S.E.	Lat. 54° 51' 15'' Long. 2° 8' 20''	
15.	"	"	Lat. 54° 53' 10'' Long. 2° 10' 40''	} Knowl Water, $\frac{1}{4}$ m. E. of Westburnhope Farm.
16.	"	"	Lat. 54° 52' 45'' Long. 2° 8' 40''	

The Great Limestone of Durham and Northumberland contains many specimens of *Dibunophyllum* and *Lonsdaleia floriformis*, and we therefore correlate it with the Upper *Dibunophyllum* zone of Bristol. The beds collected from are some 400 feet higher in the series. Westgarth Foster estimates the Great Limestone to be 408 feet below the Fell Top Limestone.

It will be observed that the only fossil found in these beds which has any affinity to the Pendleside fauna is *Chenocardiola Footii*, which has hitherto only been found in beds of that series.

Note by Dr. A. VAUGHAN.

Aulophyllum off. *Wünschi*, Thomson.

'I have carefully studied the specimen marked A. *Wünschi*, Thomson,¹ and, under the name *Wünschianum*,² differs in the possession of—

'(1) Intermediates which do not project beyond the inner wall (judging by the figure).

¹ *Phil. Soc. Glasgow*, vol. xiv. (1883), pl. 14, fig. 6, and p. 486.

² *Ibid.*, vol. xiii. (1882), p. 513.

'(2) A freer centre in the central area (again judging by the figure).

'(3) "Short and turbinate" form (see his description); but, seeing that he gives measurements which agree with those of the specimens I have examined, the above description is probably inaccurate.

'[N.B.—Thomson adds an important note on the occurrence of his type species.]¹

'*Dibunophyllum*, aff. ϕ , Vgn. \equiv *Dib.* aff. *Muirheadi*, Nicholson and Thomson.²

'The external area and structure of inner wall agree with *Dib.* ψ , Vgn.

'The central area has the simple structure of *Dib.* θ , Vgn.

'The strong prolongation of the septa to the external wall is an unusual feature in the genus.'

	Localities															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>Brachiopoda</i> —																
<i>Spirifer bisulcata</i>			*	*	*				*							
„ <i>trigonalis</i>												*				*
„ <i>glaber</i>		*														
<i>Spiriferina</i> sp.						*										
<i>Seminula ambigua</i>		*		*							*		*			*
<i>Reticularia lineata</i>			*		*				*	*	*	*			*	*
„ <i>elliptica</i>				*												
<i>Rhynchonella trilatera</i>		*			*								*			
„ <i>pleurodon</i>					*								*			
<i>Schizophoria resupinata</i>		*														
<i>Productus aculeatus</i>			*	*					*	*	*	*	*			*
„ <i>antiquatus</i>			*	*	*					*						
„ <i>cora</i>						*						*				
„ <i>costatus</i>		*														
„ <i>latissimus</i>			*						*	*	*				*	*
„ <i>longispinus</i>		*	*	*	*				*		*			*		
„ <i>Martini</i>													*		*	
„ <i>punctatus</i>			*							*	*					
„ <i>pustulosus</i>				*									*			
„ <i>scabriculus</i> , <i>Var.</i>		*	*	*									*	*		
„ <i>semireticulatus</i>			*	*							*					*
„ <i>undiferus</i>			*													
<i>Orthotetes</i> or <i>Derbya</i>		*	*		*	*	*			*				*		
<i>Orbiculoidea nitida</i>			*													
<i>Chonetes</i> aff. <i>laguessiana</i>		*	*		*				*	*		*			*	*
„ <i>Buchiana</i>															*	*
<i>Lamellibranchs</i> —																
<i>Streblopteria ornata</i> , <i>R. Eth., Jun.</i> . .	*															
<i>Pseudamusium concentricum</i>	*															
<i>Actinopteria persulcata</i> , <i>M^c Coy</i> . . .	*															
<i>Posidonomya corrugata</i> , <i>R. Eth., Jun.</i> .	*															
<i>Parallelodon bisulcata</i> , <i>Porth.</i>	*															
„ <i>semicostatus</i> , <i>M^c Coy</i>	*															
<i>Edmondia Lowickensis</i>	*															
„ <i>unioniformis</i> , <i>Phill.</i>	*															
<i>Nucula gibbosa</i> , <i>Flem.</i>	*															
<i>Nuculana attenuata</i> , <i>Flem.</i>	*															
<i>Cypricardella rectangularis</i> , <i>M^c Coy</i> .	*															
<i>Chaenocardiola</i> aff. <i>Footii</i>	*															
<i>Myalina peralata</i> , <i>de Kon.</i>	*						*									

¹ *Phil. Soc. Glasgow*, vol. xiii. (1882); see p. 487.

² *Ibid.*, vol. x. (1876), p. 129.

	Localities															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>Gasteropoda</i> —																
Pleurotomaria sp.									*							
Pileopsis sp.		*														
Loxonema sp.		*														
" <i>rugifera</i>				*	*				*							
Naticopsis sp.					*											
Euphemus Urei		*														
<i>Cephalopoda</i> —																
Orthoceras aff. Morrisianum					*											
<i>Corals</i> —																
Zaphrentis aff. enniskilleni			*												*	
Aulophyllum aff. Wünschi, <i>Thomp.</i>			*	*								*				
Dibunophyllum aff. ϕ			*								*					
Cyclophyllum aff. pachyendothecum				*												
<i>Crustacea</i> —																
Phillipsia aff. mucronata					*								*			

Mr. C. M. Cockin has demonstrated the presence of Carboniferous limestone belonging to the Cyathaxonia beds in the northern part of the South Staffordshire coalfield, at a sinking for coal at Fair Oak Colliery, near Rugeley. Apparently the whole carboniferous system below this horizon is wanting at that locality. These results were presented in a paper to the Geological Society last session.

It may serve a useful purpose to summarise the results arrived at since the Committee commenced work some years ago.

At first work was chiefly done on the series of black shales and limestone, to which Mr. J. A. Howe and I gave the name of Pendleside Series. Year by year collecting in various districts has demonstrated our thesis that these beds had a definite fauna which distinguished them from the Yoredale Series of Wensleydale. We have obtained this fauna between two very definite degrees of latitude in the Midlands; that is, the fauna has never been obtained north of the latitude of Settle, or south of the latitude of Leicester. The fauna is found to characterise beds which succeed the upper Dibunophyllum zones of the Carboniferous Limestone as far west as co. Clare and co. Limerick, Loughshinny, co. Dublin, the Isle of Man; and it also occurs E. at Visé, Clavier near Dinant, and near Mons, in Belgium.

Zones can be distinguished in the series according to the following table:—

Zone of <i>Gastrioceras Listeri</i>	} Lower Coal Measures. } Millstone grit.	
Zone of <i>Glyphioceras bilingue</i>		
Zone of <i>Glyphioceras spirale</i>	} <i>Glyphioceras diadema</i> .	
Zone of <i>Glyphioceras reticulatum</i>		
Cyathaxonia beds {	Zone of <i>Posidonomya Becheri</i>	} <i>Nomisoceras rotiforme</i>
	Zone of <i>Prolecanites compressus</i> . . . . .		D_{3}.

The whole of the Upper Carboniferous Series, comprising the Pendleside Series, Millstone Grit, and Coal Measures, might be termed the zone of *Pterinopecten papyraceus*. This fossil appears in the lowest beds, with *Posidonomya Becheri*, and marks the faunal change.

I have also shown that the Pendleside Series is represented at Bishopton

in Glamorganshire, and that the Lower Culm of Devon belongs to the *Posidonomya Becheri* beds and *Prolecanites compressus* beds.

More work is required to be done in the Millstone Grit Series, and I have in hand certain details which require working out; but further research must be done before they can be published. Attention is being given to the Coal Measure lamellibranchs in the Yorkshire and Lancashire coalfields. At present details appear to demonstrate the value of the lines that have been laid down for the North Staffordshire coalfields by Mr. J. T. Stobbs and myself.

With regard to the Lower Carboniferous Series, the whole of the south-western area of the Lower Carboniferous series has been zoned by the corals, supported by certain mutations in the species of brachiopods, by Dr. A. Vaughan and Mr. J. F. Sibly.

The same zones are, to some extent, and with local differences as to detail, demonstrated (*vide antea*) to occur in N. Wales, and most important is the fact that none of the series below the top of the Upper Seminula beds are present there.

It is more than probable that in the Derbyshire Staffordshire area the same condition of things prevails, at any rate in the west, but probably the Carboniferous Sea deepened somewhat to the east. At present, however, I have never obtained any fossils which point to a lower horizon than the lower *Dibunophyllum* beds in that area.

The uppermost beds of the Lower Carboniferous Series in Staffordshire and Derbyshire are characterised by *Cyathaxonia*, *Amplexi-zaphrentis*, *Beaumontia*, *Michilinia tenuisepta*, and *Cladochonus bacillaris*. In the upper part of this zone *Prolecanites compressus* occurs.

Below this horizon are the rich fossil deposits of Park Hill, Castleton, Narrowdale, and Wetton and Thorpe Cloud, which therefore belong to the Upper *Dibunophyllum* or *Lonsdaleia* sub-zone, but on the west side of the Pennine uplift *Lonsdaleia* is itself a very rare fossil.

In the Craven and Bolland districts of Yorkshire the same sequence obtains, the lithological structure of the rocks and the rich fossil beds of Cracoe, Settle, and Clitheroe being exactly like those of the Derbyshire area and on the same horizon. They are overlaid by *Cyathaxonia* beds, and these in turn are succeeded by *Posidonomya Becheri* beds.

In Yorkshire, however, the base of the series is seen in the neighbourhood of Ingleboro'. In the Basement conglomerate area Mr. Cosmo Johns has collected a series of corals, which Dr. A. Vaughan refers to a lower horizon than I should have expected to find there.

Dr. Vaughan thinks the fossils denote the basement beds to be on a horizon at the base of the Lower Seminula beds or Upper *Syringothyris* zones. If this is so, some interesting details must be worked out.

The whole Carboniferous series under Ingleboro' is estimated to be 1,500 feet, and 1,000 feet at least of this is characterised by Giganteid *Producti* and a fauna which I take to be of *Dibunophyllum* age. The question to be worked out is to account for the small thickness of the whole of the Seminula beds here, which are about 1,000 feet at Bristol; and in connection with this point it is to be noted that the limestones which rest on the Basement beds west of the Lake District, the Askam and Knipe Scar limestone, contain a definite *Dibunophyllum* fauna, and even further north the Lower Limestone Series of Scotland apparently belong to the *Lonsdaleia* sub-zone.

Although much has been done—it would seem that already the broad

zonal lines have been laid down for the whole of the Carboniferous Series—the Committee feel fully justified in asking for a continuance of a grant, that some of the important gaps in the chain of evidence may be filled up.

Full series of the fossils collected during the last two years have been deposited, under the care of Professor Garwood, in the Geological Department of University College, London. All outstanding expenses of collecting have been liquidated, and the Committee have now only a few shillings balance in hand for further work.

In the past nearly all the collecting has been done gratuitously, Messrs. Tate, Stobbs, and Bolton having accepted only actual out-of-pocket expenses; and they thoroughly deserve the best thanks of the Committee for their efficient services.

Investigation of the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, and at various localities in the East Riding of Yorkshire.—Report of the Committee, consisting of Mr. G. W. LAMPLUGH (Chairman), Mr. J. W. STATHER (Secretary), Dr. TEMPEST ANDERSON, Professor J. W. CARR, Rev. W. LOWER CARTER, Mr. A. R. DWERRYHOUSE, Mr. F. W. HARMER, Mr. J. H. HOWARTH, Rev. W. JOHNSON, Professor P. F. KENDALL, Mr. H. B. MUFF, Mr. E. T. NEWTON, Mr. CLEMENT REID, and Mr. THOMAS SHEPPARD.

The Speeton Shell-bed.—As mentioned in last year's report, this fossiliferous estuarine sand was first described by Professor Phillips in his 'Geology of Yorkshire' (Pt. I., p. 100), and later by Mr. G. W. Lamplugh in the 'Geological Magazine' for 1881 (p. 176). As the bed is almost always obscured by slips, so that its relations to the drift are open to question, it was decided to examine its position by excavations.

Since the presentation of the last report several excavations have been made in the neighbourhood of the exposures seen by Professor Phillips and Mr. Lamplugh, and your Committee report that, though the results obtained are corroborative of the accounts given by the observers above named, they also include certain new points of interest.

The largest excavation was made in the ridge between Middle Cliff and New Closes Cliff at Speeton, and at this place beds were exposed as follows:—

		Feet	inches
Estuarine Shell- bed	(A) Boulder clay (lower part only excavated)	. 45	0
	(B) Fine chalky gravel . . . . .	. 1	6
	(C) Yellowish sandy silt with shells . . . . .	. 6	2
	(D) Black silt . . . . .	. 4	0
	(E) Black silt with sandy streaks and a little gravel . . . . .	. 2	0
	(F) Fine gravel, chiefly of chalk . . . . .	. 4	0
	(G) Speeton clay (base of Bel. jaculum zone $1\frac{1}{2}'$ and 'Compound nodular band' $\frac{1}{2}'$, forming the upper portion of the sloping cliff of Secondary clays 84 feet above beach level).		

It will be seen from the above section that the shell-bed is here 17 feet 8 inches thick and its base is about 86 feet above the present beach.

The gravel (F) rests on the Bel. jaculum clays, but contains some material washed from the lower beds of the Speeton clay, such as fragments of *Bel. lateralis*, &c.

The excavation showed that the beds do not rest on a flat surface of Speeton clay, but that their surface dips into the cliff at an angle of 25 degrees, and that the bedding of the shelly deposit itself also dips into the cliff at about the same angle.

Shells occur throughout the silty beds, but are most plentiful in bed C. When excavating, the shells seen were *Cardium edule*, *Tellina balthica*, *Scrobicularia piperata*, and *Hydrobia*. A quantity of the shelly material was collected for washing, on which the Committee will report later.

Search was made for the shell-bed at the same level both north and south of the main excavation. Southwards no trace was observable, but northwards the beds were traced fifty yards along the slopes of New Closes Cliff.

At the foot of the cliff, about 500 yards northward of the site of the excavations, similar shelly silts were laid bare during favourable conditions of the foreshore early this year. In this exposure the beds attained a thickness of 4 to 5 feet, and were traceable for at least 100 yards. The silts rested on Kimeridge clay, and were overlain by glacial drifts which at this locality are extremely thick.

At the north end of this section the following particulars were noted :—

	Feet	inches
Boulder clay with intercalated stratified sand and gravel, not less than	120	0
Fine chalky gravel	2	0
Silt with shells	3	0
Kimeridge clay	4	0

The thanks of the Committee are due to the Right Hon. the Earl of Londesborough, for permission to investigate the shell-bed at Speeton, and to Mr. C. G. Danford, of Reighton, for help in many ways.

Index Generum et Specierum Animalium.—*Report of the Committee, consisting of* Dr. HENRY WOODWARD (*Chairman*), Dr. F. A. BATHER (*Secretary*), Dr. P. L. SCLATER, Rev. T. R. R. STEBBING, Dr. W. E. HOYLE, Hon. WALTER ROTHSCHILD, and Lord WALSINGHAM.

THE indexing of the literature for the second portion of the Index (1801–1850) has steadily progressed during the past year, but is necessarily slow, since the later in date is the book the more complicated becomes the synonymy of the nomenclature. Among the larger works dealt with may be mentioned 'Allgemeine Schweizerische Gesellschaft,' 'American Journal of Science,' 'Het Instituut,' 'Kon. Nederlandsch Instituut,' 'Anales Ciencias Nat.,' Amyot's 'Rynchota' (1848), 'Journal des Mines,' 'Annales des Sciences naturelles,' and numerous individual volumes.

The chief item of interest in bibliographical matters in the past year was the discovery of a copy of the 'Museum Humfredianum,' 1779. This had been searched for by Mr. Sherborn for fifteen years. The copy found, believed to be unique, has been presented by him to the British Museum (Natural History). The value of the find is negative, in that it proves that George Humphrey did not coin any generic names

for Mollusca in the tract, but these first appeared in his 'Museum Calonnianum,' 1797.

During the year notes were published by Mr. Sherborn on :

(1) The New Species of Birds in Vroeg's Catalogue, 1764—in conjunction with Mr. C. W. Richmond.¹

(2) The dates of publication of d'Orbigny's 'Mollusques vivans et fossiles'; his 'Paléontologie universelle des Coquilles et Mollusques,' and 'Paléontologie des Coquilles et Mollusques étrangers à la France.'²

(3) The 'Museum Humfredianum,' 1779.³

(4) The conchological writings of Capt. Thomas Brown.⁴

A copy of the rare 'Museum Boltenianum,' 1798, specially bought for the completion of Vol. I. of this Index, has now been reproduced in facsimile and published by Mr. Sherborn and Mr. E. R. Sykes. The original copy has been placed in the Library of the British Museum (Natural History).

The Committee ask for reappointment, and hope that a grant of 100*l.* may be given to this important piece of work.

The Probability of Ankylostoma becoming a Permanent Inhabitant of our Coal Mines in the Event of its Introduction.—Report of the Committee, consisting of Mr. A. E. SHIPLEY (Chairman); Mr. G. P. BIDDER (Secretary), and Mr. G. H. F. NUTTALL.

THE question of *Ankylostomiasis* in British mines has now been included in the reference to the Royal Commission appointed to inquire into and report on certain questions relating to the health and safety of miners, and a member of the Committee for 1904–05 is one of the Commissioners.

Under these circumstances the Committee do not propose to issue any further report, and recommend that they be not reappointed.

The Zoology of the Sandwich Islands.—Sixteenth Report of the Committee, consisting of Professor NEWTON (Chairman), Mr. DAVID SHARP (Secretary), Professor S. J. HICKSON, Dr. P. L. SCLATER, Dr. F. DU CANE GODMAN, and Mr. EDGAR A. SMITH.

THE Committee was appointed in 1890 and has since been annually reappointed.

A part of the Fauna Hawaiiensis, consisting of the Microlepidoptera, by Lord Walsingham, is about to be issued; and two other parts, dealing with the Coleoptera, are well advanced. Since the last report the Committee has sustained a severe loss by the death of Dr. W. T. Blanford. The Committee asks for reappointment without a grant. As its work is now nearly completed, it seems unnecessary to add a new member to replace the late Dr. Blanford.

¹ *Smithsonian Misc. Coll.*, No. 1551, 1905.

² *Journal of Conchology*, vi., 1905.

³ *Ann. Mag. Nat. Hist.* (7), xvi., 1905; *Geol. Mag.* (5), ii., 1905.

⁴ *Proc. Malac. Soc.*, vi., 1905.

Melanism in Yorkshire Lepidoptera. By G. T. PORRITT, F.L.S.

[Ordered by the General Committee to be printed *in extenso*.]

I HAVE undertaken to introduce the subject of melanism in Yorkshire Lepidoptera to the members of the Zoological Section, chiefly with a view to eliciting discussion on a subject which I feel, notwithstanding all that has been said and written upon it, we really know very little about. I may say at the outset, that I have no definite theory as to the cause of melanism to advance myself, and probably I have very little that is new to bring forward respecting it. But as Yorkshire, with parts of Lancashire, is essentially the home of this phenomenon, it was thought that a meeting of the British Association in the county ought not to be allowed to go by without some reference to it.

I need not explain to a zoological audience that by the term melanism as applied to Lepidoptera we mean an increase or substitution of black on the wings or body, or on both, at the expense of some other colour. Melanochroism, as you know, is the substitution or darkening of some colour other than black; but I have no intention of more than alluding to that, because we see comparatively little of it in Yorkshire; beyond the fact that species generally have a greater depth of colour than the same species elsewhere; but, so far as we know to the contrary, that has always been so. Some allusion will be made to leucochroism, which is the tendency in directly the opposite direction to melanism, because, although they are few, we have some marked examples, which must necessarily be taken into account in a discussion on melanism.

It is now five-and-twenty or more years since West Yorkshire lepidopterists began to notice that various species of which a black, or nearly black, specimen had occasionally been taken were producing these dark forms in increasing numbers, some of them rather rapidly. Years before then, indeed, a quite black form of the old familiar pepper moth, *Amphydasis betularia*, was well known; but although it had developed within the memory of the present generation of entomologists, it remained for years practically our only representative of real melanism. Even within my own collecting experience it was regarded as good fortune to find one among the ordinary black-and-white 'peppered' form. Now, it is not only the dominant form, but in the South-West Riding area has practically altogether ousted the original pale form. In the Huddersfield district I have seen only one pale specimen during the past nine or ten years, and a typical specimen is now quite a rarity compared with what the black form was even in my collecting experience. More recently the black form has spread all over Yorkshire and many parts of Lancashire, and is even occasionally taken in the South of England. It is most curious, too, that in this species the black form appears to have developed suddenly; *i.e.*, it was not a gradual darkening, as no intermediates were noticed in a wild state. True, our old ordinary form was rather more densely peppered, and so was darker, than was the southern type, and it often lacked the distinct zigzag black line which, to my mind, gives to many of the South of England specimens so much prettier an appearance; yet the fact remains that the specimens taken at large were, and still are, either black or, comparatively speaking, quite pale. I do

not overlook the fact that our collections do contain specimens which are intermediate, but these I believe have mostly, if not all, been bred from the egg (I have bred some myself), and only an occasional brood shows them, and artificial conditions may have had something to do with it.

Besides *Betularia*, we have now in Yorkshire at least thirty species in which melanism has become so strongly developed that in various districts—chiefly in the south-west—black or nearly black specimens of species which in other districts are pale are now regularly obtained. These are :—

Odontopera bidentata	Acronycta megacephala
Phigalia pilosaria	" ligustri
Boarmia repandata	" rumicis
Tephrosia biundularia	" menyanthidis
Fidonia atomaria	Xylophasia polyodon
Venusia cambricaria	Apamea oculea
Hybernia progemma	Miana strigilis
Oporabia dilutata	Agrotis agathina
Larentia multistrigaria	Epunda viminalis
Eupithecia castigata	Hydrocampa nymphæalis
" albipunctata	Scoparia mercurialis
Hypsipetes impluviata	Tortrix pyrastrana
" elutata	Sciaphila virgaureana
Cidaria russata	" octomaculana
" immanata	Diurnea fagella

In the following of these—*Hypsipetes impluviata*, *Hypsipetes elutata*, *Acronycta rumicis*, *Xylophasia polyodon*, *Apamea oculea*, *Miana strigilis*, *Epunda viminalis*, and possibly one or two others—the melanism is *not* of recent development. They have been dark in Yorkshire ever since any interest was taken in Lepidoptera, and consequently, whether they were originally pale with us we are now unable to determine. The others have become dark, or at any rate the dark specimens have largely increased in numbers, during the collecting experience of many of our present-day lepidopterists. More than this, there are at the present time quite a number of species of which specimens so much darker than the typical forms are so frequently taken as to indicate that they too are being influenced towards the same end. These include :—

Hepialus hectus (the female)	Xylophasia rurea
Arctia fuliginosa	Agrotis segetum
" mendica	" tritici
" lubricipeda	Polia flavocincta
Bombyx quercus (var. callunæ)	" chi
Ennomos fuscantaria	Agriopsis Aprilina
Abraxas ulmata	Aplecta nebulosa
Hybernia aurantiaria	Hadena dentina
" defoliaria	Cloantha solidaginis
Eubolia palumbaria	Scoparia cembra
Cymatophora diluta	

and probably many of the Micro-lepidoptera. In two or three of these, however (not more), the darkening is more melanochroic than truly melanic.

It is not necessary for our purpose to-day to detail the histories of all these melanic species; still, remarks on some of the more prominent may tend to elucidate the subject.

As before stated, melanism was known in *Amphydasis betularia* long before it was observed in any other species; then it seemed to develop in:

several almost simultaneously. These were *Phigalia pilosaria*, *Tephrosia biundularia*, *Hybernia progemmaria*, and *Diurnea fagella*. In three of these, and probably in *Diurnea fagella* as well, the darkening was gradual, but fairly rapid; and in the case of two, and probably of all the three apterous species, the females were the first to succumb to the darkening influence. The melanism in these four species dates back probably to about 1880; but I am less sure about *Diurnea fagella* than the others, as, not being so much interested in Micro-lepidoptera, I had scarcely noticed this species critically for many years prior to 1886. Twenty years or so before then, however, *Fagella* was very familiar to me as the pale grey 'March Dagger' moth, the males of which sat in plenty on the tree trunks in our woods. But in the spring of 1886, wanting a series of the moth, I one evening (on April 27) went after dark into a small wood just outside the town of Huddersfield, and very soon picked off the oak trunks 120 specimens, of which probably 50 were females, and out of the lot two only, one of each sex, were of the pale type. Both sexes were in profusion on the tree trunks, but practically all dark. Of *Phigalia pilosaria* and *Hybernia progemmaria*, I fancy the females were almost all black for some time prior to 1886; but certain it is that they were so when we first began to notice that the males were rapidly becoming darker. At first the unicolorous black males were not common, but there were plenty intermediates, and year by year the dark ones increased, and now in the case of *Progemmaria* in some districts largely predominate, whilst in both species it is almost impossible to find one as pale as the southern forms. I believe the same remarks will apply to *Tephrosia biundularia*, but as the species occurs but very rarely in my own immediate district, I have not had the opportunity of noticing it so closely, and so am unable to say whether the females became dark before the males. In passing I wish you to note, because it will probably affect our discussion afterwards, that the apterous females of three of these species do *not* much affect tree trunks in the daytime. The males of two of them do, and of *Progemmaria* a very few do. An occasional female of any of them may now and again be found in such situation, but probably not near 1 per cent. of what may be found after dark with the aid of a lamp.

The next species to startle us was *Boarmia repandata*, in 1887. In that case Mr. George Kilner Crosland and myself, when working one afternoon in a pine wood near Netherton, Huddersfield, found the species freely on the pine trunks, a large proportion of the specimens evidently having been black, but, having been out some time had then a somewhat shabby appearance about them. From specimens boxed, however, eggs were obtained which produced in 1888 a series of moths which, without any exaggeration, were as black as ink, though a large number of the brood were of a very dark-brown colour. Since then the black form has become quite common in several woods in South-west Yorkshire, and larvae collected indiscriminately in these woods in spring now produce, I believe, a considerable preponderance of black or nearly black moths. I must state here, however, that this form was certainly not *new* in 1887, for in a store-box of Huddersfield-collected moths, and which I have no doubt were quite fifty years old, I found some years ago two worn specimens of what undoubtedly had been black *Repandata*. The man who collected them (now dead) had a cabinet and collection, but I believe I am right in saying that all the specimens of *Repandata* in his series were ordinary; and whether these two dark ones had been considered as too bad to put

in, or had been in and afterwards thrown out, I do not know. But it proves, at any rate, that there was long ago a latent tendency in the species to become melanic, and that it is quite possible it may even have been common long before we noticed it.¹

A moth which for thirty years of my collecting experience was always regarded as one of our most constant species, showing little colour variation, was *Odontopera bidentata*, the Yorkshire form being of a soft, rather pale greyish brown colour. But about ten years ago came the report from Wakefield that a quite black specimen had been taken there, followed during the next several years by a few others. Now at Wakefield, and at Methley some six miles away, it is quite plentiful, so much so that Mr. George Parkin, who resides in the city of Wakefield, told me that last year, in one week, out of the only five specimens which flew into his house, attracted by the light, four were black, and that so rapidly is the form increasing, he thinks that in a few more years the pale form will be quite eliminated! This, too, may be regarded as a sudden rather than a gradual change, for although a few rather darker than ordinary examples do occur, they cannot be regarded as even intermediate forms. In 1904, from a few eggs deposited by a captured black moth, I bred nine specimens, six of which were black and three ordinary. From the black moths in the following year, 1905, I reared a very large brood, about 75 per cent. of which were black; and from them again this year I bred a considerable number, of which the percentage of black was still greater. Three generations thus produced an almost entirely black race, which proves that the hereditary tendency towards melanism must be remarkably strong.

The history of the melanism of *Polia chi* shows a gradual darkening from almost white to dark slate colour, and is interesting as occurring in the first Noctua we have yet considered. It is, too, a case of specially local melanism, inasmuch as in my own district, at any rate, although occurring very markedly on the walls all around the town and surrounding villages of Huddersfield; on the equally black, or even blacker, walls bordering our high moors, only half a dozen or so miles away, almost all the specimens are of the palest form and can readily be seen from a considerable distance. This fact should be noted for our after-discussion.

Perhaps the most rapid case of change in colour we have yet noticed has been in *Larentia multistrigaria*. The species has always occurred in abundance in my own district, but up to about 1895 a dark specimen had never been observed in it, although a single black example—and one only—was known to have emanated from the district. Now nearly forty years ago the late Henry Doubleday wrote to the late James Varley, formerly a prominent lepidopterist in Huddersfield, for eggs of *Multistrigaria*, and I distinctly remember Varley telling me that from the eggs he had sent him Mr. Doubleday had bred a black *Multistrigaria*, and the specimen, I believe, is still in the Doubleday Collection at Bethnal Green Museum. Here we have another instance of the latent tendency to melanism, which in this species was not really developed until over thirty years afterwards.

In ten years' time the black form has so increased in numbers that Mr. Morley tells us that in some parts of the Skelmanthorpe district the

¹ Cf. Porritt, *Trans. Ent. Soc. London*, 1889, pl. 411, p. xiv., on melanism in *Arctia mendica* near Huddersfield.

race will evidently soon be entirely black; and my own experience in another part of the Huddersfield district strongly supports Mr. Morley's opinion. In captivity, as in *Bidentata*, three generations have almost entirely eliminated the typical form, for of some seventy specimens I bred in the spring of this year only five or six were pale. Now mark, *Multistrigaria* does not affect either tree trunks or walls in the daytime. Indeed, there are no trees on the spot I collect it at Huddersfield. It frequents old meadow hillsides overgrown with its food-plant, the white-flowering *Galium saxatile*, and although at night with the aid of a lamp many may be found sitting on the boundary walls, only a very occasional specimen can be found in such situation in the daytime, probably not one in five hundred of the specimens which we know are actually in the immediate neighbourhood. They hide apparently among or underneath the *Galium* and surrounding grasses, and are absolutely out of evidence until dusk.

One of the most recent cases of melanism, so far as our knowledge goes, is that in *Venusia cambricaria*, and it is specially interesting because it takes two distinct forms in widely separate districts. The form first noticed was by Mr. T. A. Lofthouse in a wood in the Cleveland district, and consisted in a large increase in the black on the ordinary pale ground of the anterior wings, the hind wings being almost normal. Mr. L. S. Brady afterwards turned up in a wood near Sheffield a form in which the markings are normal, but on a deep lead ground colour, which colour pertains to both fore and hind wings. Mr. Brady took me to this wood last year, when the moth was out in plenty, and I think quite 80 per cent. were of the melanic form; the percentage of the Cleveland form I understand is almost as large. Both forms are distinctly melanic, but it is curious and remarkable that the melanism should take altogether different directions in the two districts.

Our most recent find of melanism is that of *Agrotis agathina*, which was only noticed last year. In June, on a small isolated heath on the outskirts of Huddersfield, Mr. B. Morley collected a number of larvæ of the species, and from them he bred fifteen moths which were altogether much darker than anything we previously knew in the species. That particular piece of moorland had never previously been worked, consequently we know nothing as to how long *Agathina* had been black on it.

Certainly one of our most puzzling cases of melanism is that of *Acronycta menyanthidis*. The normal form of the species is greyish white with black markings, but on the heaths near Selby and York, where there is little other melanism, a quite black form is plentiful. The curious feature is that although the species is abundant right in the area of the most pronounced melanism in South-west Yorkshire, the specimens there are invariably of the palest form we know, and a black one is never seen. Mr. Samuel Walker tells me that at York no specimen is ever seen so pale as the West Yorkshire moth.

Before leaving the cases of Yorkshire melanism I ought to allude to one—one also of our oldest—in which there has been *no* increase in numbers. I mean *Abraxas grossulariata*. A very striking, almost black, form of this abundant and well-known moth (our common garden Magpie Moth) was bred in some numbers by Mr. James Varley, of Huddersfield, as long ago as 1864, and has occurred very sparingly in the same and other South-west Yorkshire districts ever since, but is still as rare as it was forty-two years ago. Indeed, the variety *Varleyata*, for

such it was afterwards named, is to-day one of the greatest prizes a lepidopterist can obtain.

Unless melanism is a distinct disadvantage to this moth, there seems to be no apparent reason why it should not have increased as much and as rapidly as any of our melanic species, because I have proved, only this season, that its hereditary tendency is stronger than in any other with which I have experimented. At the end of June last year I was fortunate enough to get a pairing from fine examples of the variety, bred from wild larvæ, and from the eggs deposited, in June this year I reared a considerable brood of the moth. Every specimen, without exception, was of the extreme form of *Varleyata*. Now, even in its few known localities (for it does not appear to occur at all in most places, even in the districts which have produced it), the specimens reared by collectors only average about three for every thousand larvæ; so it is highly improbable that both parents of my last year's pair of moths were variety *Varleyata*—possibly neither of them were; yet not a single specimen from my brood showed the slightest inclination to revert to the ordinary or any other form than *Varleyata*. This has never occurred to me in any other species.

Of course melanism is not confined to Yorkshire and Lancashire. There is plenty of it in Scotland, although generally, Scotch insects are paler than the same species in Yorkshire. *Rusina tenebrosa* at Rannoch is much darker and smaller than is the Yorkshire insect. Black *Xylophasia polyodon* are more plentiful in Scotland than in Yorkshire. Several species are melanic in the Shetland Isles which are normal in Yorkshire—notably *Noctua glareosa*, which, almost black there, is pale slaty grey or pale pink or rosy in Yorkshire. I have seen one Yorkshire specimen, taken near Barnsley, of exactly the darkest Shetland form, so possibly the species here is in process of development towards melanism. I can only say, however, that, with the exception of the specimen alluded to, I can see no difference as yet in the species compared with what it was thirty years ago. Melanic *Dianthæcia conspersa* are common in the Shetland Isles, but quite normal in Yorkshire; the species, however, does not occur in the south-west of our county, and so not in the area of melanism. In Delamere Forest, Cheshire, a black form of *Aplecta nebulosa* has been known as plentiful for some years, but although the species has apparently been increasing in depth of colour for some time, the extreme black Delamere form, variety *Robsoni*, was only noted here for the first time last year, when a specimen was captured by Mr. Arthur Whitaker in Haw Park, Wakefield. Delamere Forest, too, produces a very fine melanic form of *Macaria liturata*, which as yet has not been found at all in either Yorkshire or Lancashire, though the species occurs right in the melanic area. Even the extreme south of England has its representatives of melanism. In a wood near Maidstone, Kent, Mr. Goodwin takes a quite black form of *Tephrosia consonaria*, and in the same wood almost black *Boarmia consortaria*, neither of which species are known to be melanic anywhere else. They do not, however, occur in Yorkshire at all; had they done so it is fair to assume they would probably have become black long before they did so in Kent. The genera *Boarmia* and *Tephrosia*, indeed, seem particularly prone to melanism, as, besides the species already alluded to, it occurs in *Boarmia rhomboidaria*, *Boarmia abietaria*, *Boarmia roboraria*, and I have seen it in all the British species of *Tephrosia* except *punctulata*. London has its

own special cases of melanism, the most recent and noteworthy being the fine purple-black form of *Heperophila abruptaria*, at present almost confined to North London. The black variety of *Eupithecia rectangulata*, black *Boarmia rhomboidaria*, and the darkest *Acronycta psi* are largely London forms, though the West Yorkshire *Rhomboidaria* (variety *Perfumaria*) does strongly approach the London moth.

A few words on Yorkshire leucochroism, inasmuch as it must be considered in its bearings on local melanism, and we will pass on to the immediate object of our meeting this morning. There is little of it in our county, but with the main tendency so strongly in the opposite direction, why should there be any at all?

Perhaps our most remarkable example is *Cidaria suffumata*. A melanic form of the species, variety *piceata*, occurs pretty commonly in Scotland, and ought, judging from all our experience with other species, to be still commoner in West Yorkshire. But it is not—scarcely occurs at all. Indeed, the only West Yorkshire record I know is by Mr. Arthur Whitaker, who found a specimen at Worsbrough, near Barnsley; and it is almost as rare in the other parts of the county. The tendency of the species is distinctly to become paler. Mr. B. Morley, who for many years has had great experience with the species, puts the matter so very clearly that I cannot do better than quote his remarks. He says: 'Last spring I netted a few *Suffumata*, using no discrimination whatever, only for those in the best condition. In due time, when pinned in the cabinet, the difference in comparison with others taken on the same hedgerow seven years ago was very striking indeed. The lighter parts of the wings were more clear, and the central band darker. In the same locality a brighter (*i.e.*, paler) form than this is frequently taken, and very rarely the extreme pale form, variety *Porrittii*, is obtained also. It seems probable that the extreme form, now so rare, is in reality the forerunner of what the species will become locally. It may be of interest to note that the dark variety *Piceata*, which occurs in some parts of the north of the county, has never been recorded here. One would expect that the dark form would be the natural variation of the species in this district, where melanism predominates, in comparison with any other variation, especially when it is remembered that the dark variety *Piceata* is by far the commonest form of variation in the species in these islands.' The only locality in Britain, besides the West Riding district, where the pale forms are known to occur is Dover, and it seems unaccountable that in so common and widely distributed a species the variety should not occur between Yorkshire and Kent.

Another Yorkshire leucochroic species is the familiar pine-frequenting *Fidonia piniaria*. Here, and indeed throughout the north of Britain, the ground colour of the wings of the male is pure white, whereas in the south of England woods it is yellow. The species abounds all over the melanic area of West Yorkshire, yet seems to be absolutely proof against any tendency to darkening. Why is this? The same thing occurs with a somewhat closely allied species, *Strenia clathrata*, which, however, does not occur in South-West Yorkshire. It is abundant on the coast at Scarborough, the ground colour, in my experience, being always white, whereas in the south of England it is yellow. Yet that there is a tendency in the genus *Fidonia* to melanism is proved by the common *Fidonia atomaria* occasionally being black in South-West Yorkshire.

¹ *Naturalist*, February 1906, pp. 48-9.

Enough has probably been said as to the indisputable fact of melanism, and it is time to get on to our discussion as to the 'Why' and the Cause or Causes of the phenomenon. As we all know, the generally accepted theory as to the 'Why' is that it is a means of protection. But is it really a protection? And from what? We have been told over and over again that birds are the natural enemies of our moths, and that the pale forms, being so much more conspicuous on our darkened tree trunks, the birds pick them off, and the darker specimens, being less conspicuous, are more likely to escape detection, and so escape in proportionately greater numbers and are left to perpetuate still darker forms. But *do* birds feed to any extent on moths? My own experience certainly does not warrant any such conclusion. Many lepidopterists here will bear me out when I say that if, in an early morning's walk in the woods, one espies any moth, however pale and conspicuous, on a tree trunk, and does not happen to have a box in his pocket, it may safely be left there until towards evening, when one has time to fetch it. In ninety-nine cases out of the hundred the moth will be there just as when left in the morning, notwithstanding that the wood may be alive with insectivorous birds. Birds, as we all know, feed largely, many species almost exclusively, on caterpillars, and I have always maintained that the chief use of the Lepidoptera in the economy of Nature is to provide food for birds as larvæ; but if the birds fed on the moths themselves, would it not be a case of 'killing the goose that lays the golden eggs'? You may go on to one of our heaths on a fine late afternoon or early evening, and see the place absolutely alive with Micro-lepidoptera on the wing, and at the same time the swallows feeding on the Diptera high up; but they are not taking the moths, which are flying in myriads a few inches above the heather. The only bird I remember which seems to live upon moths is the goatsucker, and he undoubtedly does get rid of an enormous quantity. But the goat-sucker only feeds at night, and always catches his meal on the wing, so the colour assimilation to tree trunks cannot apply to it. The same remark applies to bats, which also account for the slaughter of myriads of moths; but it is only at night, and we can scarcely conceive that a dark moth would have any better chance of escape than a pale one from the eyes of either a goatsucker or a bat. Dragon-flies certainly take moths in the daytime, but they hawk for them and take them on the wing, never, I should say, from a tree trunk. Besides, we have comparatively few dragon-flies in Yorkshire, and certainly far less in the melanic area than in any other part of the county. The big green grasshopper (*Locusta viridissima*) is a deadly enemy to moths, but it does not occur in Yorkshire at all. On the Deal sandhills, and on the South Devon coast, I have often seen them perched on the tops of sugared posts, waiting for the moths to come up, and have seen one seize and devour immediately a large *Xylophasia polyodon*. Only last August, on a marshy part of the Deal sandhills, I saw these grasshoppers in profusion perched after dark on the tops of the thistles, deliberately waiting to pounce on the moths as they visited, as they do in large numbers, the thistle flowers. There was no melanism in the moths there, but if there had been it would not have protected them one atom. Hence I cannot see my way to assent to the theory that the primary reason of melanism is for protection against such enemies.

Melanism is with us, strongly, and is still increasing; but what *do* we know as to its cause?

It has been noticed that the areas of melanism are generally in those large manufacturing districts which have a humid atmosphere or heavy rainfall, and hence it has been assumed that smoke and moisture, aided by natural selection, have produced the phenomenon. Mr. Tutt has argued the case from this standpoint at great length in his pamphlet 'Melanism and Melanochroism in British Lepidoptera.' No doubt it is true that melanism is almost confined to the western side of Britain—that is, the side most strongly influenced by the Gulf Stream; and also that it is most prevalent in the manufacturing, and consequently smoky, districts of our island. But if smoke is an essential, how are we to account for the numerous and marked examples of melanism in the Hebrides and the Shetlands and Orkneys, where there is no smoke? As we have already seen, extreme melanism occurs there in many species which in the melanic area of South-west Yorkshire are not at all affected by it, and *vice versa*. And if in these districts it is caused by humidity only, why do we find that in the fen and marshy districts of Norfolk and Cambridgeshire, where species absolutely live in fog and damp, and a humid atmosphere as well, there is practically no melanism? I know Mr. Tutt maintains that in the fen districts there is plenty of melanism, but I can only say that, with a large experience of fen collecting, I have never seen it. That there are plenty of dark specimens of such species as *Chilo phragmitellus* among the pale ones I admit, but such are not at all on 'all fours' with true melanism as we understand it in Yorkshire. Again, if smoke and humidity cause melanism in Yorkshire, how is it that in the melanic area some species which we know have a latent tendency to melanism are not there affected by it? That the latent tendency to melanism in *Acronycta menyanthidis* is strong we are sure from the fact that it is developed in extreme form at Selby and York, independent of smoke; but although it occurs right on the spot where numerous other species, including one in the same genus, have succumbed, it remains there absolutely untouched, though its habits in both areas are the same.

An almost analogous case is that of *Noctua glareosa* in the Shetland Isles. There is no smoke there, and still, in apparently similar localities, and with the same habits, melanism occurs strongly in the species. Yet in South Yorkshire, although occurring in plenty with many of our most melanic moths, it retains practically untouched its pale character.

Then, supposing that smoke and humidity *do* cause melanism, we have to face the question as to *how* they cause it. The obvious answer is, of course, that it is natural selection in the first place, followed up by heredity. But surely, if natural selection operated on the few chance specimens which were a little darker than the type, we should have seen a *gradual* darkening in all melanic species; whereas we are pretty certain that in many no such thing has occurred. And it is just here, I think, where our great difficulty lies. After the first dark specimens, if in sufficient numbers, heredity is quite sufficient to account for a rapid increase, if we allow that the darkening is in any way a distinct advantage to the species; for we have proved over and over again by breeding that the progeny of melanic parents have an inherent tendency to become still darker with each successive generation.

I have not alluded to a theory I have seen argued, to the effect that melanism may be a reversion to the original forms of the various species,

because I am convinced we have no reason to believe that at any former time our melanic species were dark ; and if they were, there is still less probability, nay, possibility, that they should revert to such forms, unless the atmospheric and all other conditions of their former existence were again to become the same.

As I stated at the beginning of my remarks, I only undertook to introduce the subject, with a view to eliciting possible theories from others, and if, from the facts I have given, any satisfactory deduction can be drawn, our time this morning will not have been wasted.

Madreporaria of the Bermuda Islands.—Report of the Committee, consisting of Professor S. J. HICKSON (Chairman), Dr. W. E. HOYLE (Secretary), Dr. F. F. BLACKMAN, Mr. J. S. GARDINER, Professor W. A. HERDMAN, Mr. A. C. SEWARD, Professor C. S. SHERRINGTON, and Mr. A. G. TANSLEY, appointed to conduct an investigation into the Madreporaria of the Bermuda Islands.

THE Committee report that they have been unable to secure the services of a competent naturalist to carry on this investigation. The Committee do not ask to be reappointed.

Occupation of a Table at the Marine Laboratory, Plymouth.—Report of the Committee, consisting of Mr. W. GARSTANG (Chairman and Secretary), Professor E. RAY LANKESTER, Mr. A. SEDGWICK, Professor SYDNEY H. VINES, and Professor W. F. R. WELDON.

THE Committee beg leave to report that Miss Sollas was unable to occupy the table at Plymouth this year, and consequently it was not filled. As the Association is entitled as a Governor of the Marine Biological Association to nominate to a table at the Laboratory for one month in each year, the Committee ask to be reappointed without a grant.

Colour-physiology of the Higher Crustacea.—Report of the Committee, consisting of Professor S. J. HICKSON (Chairman), Dr. F. W. GAMBLE (Secretary), Dr. W. E. HOYLE, and Mr. F. W. KEEBLE, appointed to enable Dr. F. W. Gamble and Mr. Keeble to conduct Researches on the relation between Respiratory Phenomena and Colour Changes in the Higher Crustacea.

During the past summer Dr. Gamble and Mr. Keeble have carried out a further spell of experimental work at Trégastel, Brittany, on the origin and functions of the pigmented cells (zoochlorellæ) of *Convoluta*. The results were communicated to the Royal Society in November by Professor Hickson, F.R.S., and published in the 'Proceedings' under the title 'Isolation of the Infecting Organism of *Convoluta roscoffensis*.'

The organism which Messrs. Gamble and Keeble have isolated has close relations with the Chlamydomonadinae. By suitable methods culture of this organism have been obtained on the egg-capsules of *Convoluta*. When taken from these cultures samples of the organism

were found to give rise to infection in 'sterilised' *Convoluta*, whereas control experiments with similar batches of developing young *Convoluta* showed no infection.

This work has since been followed up by a prolonged histological investigation into the fine structure of the infecting organism at different stages of its career, both when free in the egg-capsule of *Convoluta* and when ingested by the worm. The results of this work are almost ready for publication, and show that the green cell undergoes important changes within the body of its host.

This work has arisen out of the research conducted by Messrs. Gamble and Keeble on the pigment of Crustacea, and forms part of the experimental programme which these authors have in hand bearing on the presence and functions of pigment in the lower animals. In reference to this topic the following experiments have been carried out and will be continued by Messrs. Gamble and Keeble. The results of cultivating *Hippolyte varians* under varying intensities of incident and reflected light; the function of the green cells in *Hydra* when placed under known cultural conditions; the nature and function of the 'yellow bodies' in *Poly-stomella*.

The Committee ask to be reappointed, with permission to retain the unexpended balance of the grant.

The Freshwater Fishes of South Africa, with special reference to those of the Zambesi.—Interim Report of the Committee, consisting of Mr. G. A. BOULENGER (Chairman), Dr. J. D. F. GILCHRIST (Secretary), and Mr. W. L. SCLATER.

THE whole of the grant (50*l.*) has been spent by Dr. Gilchrist in securing specimens, in providing apparatus for the capture and preservation of fishes, and in issuing circulars in order to enlist assistance in procuring them from various parts of South Africa.

Dr. Gilchrist writes that he has sent to the various Governments copies of a little pamphlet on the preserving and sending of fish, and that he has already received some replies. He has also sent off from Cape Town five boxes with formalin, but they have not yet been returned to him. He has himself collected a good many specimens from various parts of Cape Colony and from the Transvaal, and has received a series procured in the Northern Transvaal by Dr. Gunning.

Zoology Organisation.—Report of the Committee, consisting of Professors E. RAY LANKESTER (Chairman), S. J. HICKSON (Secretary), T. W. BRIDGE, J. COSSAR EWART, M. HARTOG, W. A. HERDMAN, and J. GRAHAM KERR, Mr. O. H. LATTER, Professor E. A. MINCHIN, Dr. P. C. MITCHELL, Professor C. LLOYD MORGAN, Professor E. B. POULTON, Mr. A. SEDGWICK, Mr. A. E. SHIPLEY, and Rev. T. R. R. STEBBING.

THE Committee arranged for a meeting of zoologists in Edinburgh on March 30, 1906. Sir John Murray was voted into the chair, and a discussion took place on the Teaching of Natural History in the schools of

Scotland. The meeting was attended by twenty-one persons. A vote of thanks to the Royal Society of Edinburgh for the loan of the Society's rooms for the purpose of the meeting was passed.

The Committee ask to be reappointed.

The Influence of Salt and other Solutions on the Development of the Frog.—Report of the Committee, consisting of Professor G. C. BOURNE (Chairman), Mr. J. W. JENKINSON (Secretary), and Professor S. J. HICKSON. (Drawn up by the Secretary.)

I. On the Effect of certain Solutions upon the Developing Egg.

A. As has been set forth in previous reports, the solutions employed may be classified, according to the effects they produce, as follows:—

i. Those which kill the egg in an early stage (segmentation or gastrulation); e.g., NH_4I , CaCl_2 .

ii. Those which kill the egg during the formation of the medullary folds; e.g., NaI .

iii. Solutions which allow development to proceed but disturb it—

(α) The embryo remains more or less spherical. The medullary groove usually remains open, the yolk-plug usually persists; e.g., LiCl , KCl .

(β) The embryo elongates; differentiation is greater than before.

1. Blastopore and medullary groove remain open; e.g., NaCl , K_2SO_4 .

2. The blastopore closes, the medullary folds remain wholly or partly open.

Cane sugar and magnesium salts.

iv. In dextrose development is retarded, but is normal in form.

v. Solutions in which development is normal both in form and rate.

(α) In urea the tadpoles die.

(β) In Na_2SO_4 they remain alive.

B. It was also pointed out—

1. That these diverse effects cannot possibly all be due to the increased osmotic pressure of the medium, and to that alone;

2. But that the part conceivably played by the osmotic pressure in any particular case cannot be determined until the permeability of the tissues of the embryo to the substance is known.

3. That since Davenport has shown that the tadpoles absorb water at a very rapid rate, they are presumably very sensitive to a loss of water, and hence a means is afforded, by observing the effect of these solutions upon the tadpole, of ascertaining the permeability of the tadpole, and so, indirectly, of the egg and embryo, to the substances employed.

C. It was then shown that the tissues of the tadpole are permeable to urea and Na_2SO_4 , more or less impermeable to cane sugar and NaCl , and more to the former than to the latter.

During the present year this experiment has been continued, and it has been demonstrated that the tadpoles are permeable to the magnesium salts, more or less impermeable to dextrose, but not quite so impermeable as to NaCl .

D. Hence, assuming that the permeability of the egg and embryo is the same as that of the tadpole, it follows that the increased osmotic pressure cannot be regarded as the cause of the persistent yolk-plug and open medullary groove.

E. This conclusion is confirmed by the results of some 'desiccation' experiments.

As soon as the dorsal lip of the blastopore had appeared, the jelly of the eggs was allowed to dry up to such an extent that the eggs became strongly flattened against the glass slide on which they were placed, and assumed the form of a plano-convex lens.

Nevertheless, development continued, and *both blastopore and medulla closed*.

F. It seems highly probable that the embryo does not need to absorb water from outside during the closure of the blastopore.

II *On the Symmetry of the Egg and the Symmetry of the Embryo.*

The controversy in which Roux, Hertwig, and others have been engaged, as to the exact relation between the first furrow and the sagittal plane, hardly needs recalling. It is also well known now that the problem demands a knowledge of the position in each of a large number of eggs of not merely these two planes, but of the sperm-path and the plane of symmetry of the unsegmented egg as well. An attempt has been made to acquire a sufficiently large number of observations.

(*a*) The positions of the plane of symmetry, first furrow, and sagittal plane have been accurately determined in a considerable number of eggs. The result is—

(1) There is a tendency for the first furrow and the sagittal plane to coincide, but there is *no correlation between them*.

(2) There is a much stronger tendency for the sagittal plane to lie in the plane of symmetry, and a considerable correlation between them.

(3) The first furrow tends to lie either in or at right angles to the plane of symmetry.

(*β*) The plane of symmetry is itself said to be determined by the point of entry and path of the spermatozoon.

Observations are now being made with a view to ascertaining the correctness of this view and the correlations between sperm-path, plane of symmetry, and first furrow.

III. Experiments have been begun on the possible influence of the direction of light or heat in determining the deviation of the sagittal plane from the plane of the first furrow. As far as they go they seem to show a tendency of the sagittal plane to lie either in or at right angles to the direction of the incidence of light (or heat).

It is proposed to continue these experiments with light of various colours, and also to institute a series of investigations into the effect of light upon the development of the egg and embryo. For these reasons the Committee ask to be reappointed, with a renewal of the grant.

Occupation of a Table at the Zoological Station at Naples.—*Report of the Committee, consisting of Professor S. J. HICKSON (Chairman), Rev. T. R. R. STEBBING (Secretary), Professor E. RAY LANKESTER, Professor W. F. R. WELDON, Mr. A. SEDGWICK, Professor W. C. McINTOSH, and Mr. G. P. BIDDER.*

THE Committee report that the Association's table at the Zoological Station at Naples was occupied by Mr. G. P. Farran during September 1905, by Mr. E. S. Goodrich, F.R.S., from the middle of December 1905 to the middle of January 1906, by Professor J. Arthur Thomson during a part of January 1906, by Dr. J. H. Ashworth during March and April 1906, and by Mr. T. J. Anderson during a part of May 1906.

The work of Mr. Anderson was considerably affected by the serious eruption of Vesuvius, the Hydroids of the Bay of Naples being destroyed by the showers of fine ash, and he has sent us no further report than that he was unable to complete his research.

The reports of the other naturalists are appended.

The Committee understand that the damage done to the fauna of the Bay is likely to be of a temporary nature only. They note with sorrow the early and unexpected death of their colleague Professor Weldon, and, with the consequent omission of his name, they desire to be reappointed and ask for the requisite grant of 100*l.*

Report of Mr. G. P. FARRAN.

During the greater part of the month of September 1905, through the kindness of the British Association Committee, I occupied a table at the Zoological Laboratory at Naples. While I was there I spent my time in examining the anatomy of as many species of Tectibranchs as I could obtain in a live state, with special reference to the morphology and innervation of the mantle. The subject has, however, been so thoroughly worked out by Pelseneer, Mazzarelli, Vayssière, and others that in the short time at my disposal I was unable to do more than go over the ground that is already well known through their works.

Report of Professor J. ARTHUR THOMSON.

During my short occupancy of the table I was able to work over more than a score of Mediterranean Alcyonarians. I came upon what seems to me to be a specimen of the apparently rare *Gorgonella bianci*, von Koch, and I was able to supplement von Koch's all too brief description. In strictness it should be referred to the genus *Leptogorgia*. In the collection which was generously submitted to my investigation I found *Sarcodictyon catenata*, which has, I think, been omitted from the Mediterranean list. Of some interest was a form of *Isidella* from deep water, which was in various respects different from the typical *Isidella elongata*. I also studied what seems to me a new species of *Scirpearella* or *Ellisella*, of which I shall shortly publish a description. Finally I was able to make some observations on spicule-formation in fresh

specimens. My hearty thanks are tendered to the British Association Committee for allowing me to occupy the table, and to the Director and officers of the Zoological Station for the great facilities they afforded me.

Report of Mr. E. S. GOODRICH, F.R.S.

During a short stay in Naples last winter I occupied the British Association table in the Zoological Station from the middle of December 1905 to the middle of January 1906. Most of my time there was spent in working out the nerve-supply of the paired and unpaired fins of Elasmobranch fishes, and in making experiments with a view of ascertaining the true nature of the plexus of motor nerves. The results of these experiments have been published in the last number of the 'Quarterly Journal of Microscopical Science.' I also reinvestigated the structure of the nephridia of *Amphioxus*, and confirmed the observations made some years ago. Professor Boveri criticised the account I gave in 1902, and maintained that the nephridia open into the coelom; that no such openings exist, and that my original description was correct, I am now thoroughly convinced.

Report of Dr. J. H. ASHWORTH.

I beg to thank the Committee of the British Association for the use of the table at the Naples Zoological Station. My occupancy of the table extended from March 22 to April 19. Most of this time was spent in the study of the structure and physiology of the nervous system of *Hulla*. Some account of these researches will be included in a memoir which is in course of preparation.

The Quantity and Composition of Rainfall and of Lake and River Discharge.—Interim Report of the Committee, consisting of Sir JOHN MURRAY (Chairman), Professor A. B. MACALLUM and Dr. A. J. HERBERTSON (Secretaries), Sir B. BAKER, Professor W. M. DAVIS, Professor P. F. FRANKLAND, Mr. A. D. HALL, Mr. E. H. V. MELVILLE, Dr. H. R. MILL, Professor A. PENCK, and Mr. W. WHITAKER.

THE first aim was to tabulate the results of various researches and observations on the quantity and composition of the rainfall and lake and river water, and efforts were directed to the preparation of a bibliography. This has taken a great deal of time, and is not yet completed.

The reappointment of the Committee is asked for, with the addition of Mr. A. Strahan, F.R.S., and Mr. N. F. MacKenzie, M.Inst.C.E., and the unexpended balance of the grant.

Investigations in the Indian Ocean.—First Report of the Committee, consisting of Sir JOHN MURRAY (Chairman), Mr. J. STANLEY GARDINER (Secretary), Captain E. W. CREAK, Professors W. A. HERDMAN, S. J. HICKSON, and J. W. JUDD, Mr. J. J. LISTER, and Dr. H. R. MILL, appointed to carry on an Expedition to investigate the Indian Ocean between India and South Africa, in view of a possible land connection, to examine the deep submerged banks, the Nazareth and Saya de Malha, and also the distribution of marine animals.

THE Committee record with deep regret the deaths of Dr. W. T. Blanford, F.R.S., who was especially interested in the question of the former connection between India and South Africa, and of Rear-Admiral Sir W. J. L. Wharton, K.C.B., F.R.S., late Hydrographer to the Admiralty, both members of this Committee.

The Committee regret that they were unable to present a report in 1905. They have now received the following report from Mr. J. Stanley Gardiner, who has had charge of the work :—

Ceylon to Chagos.

Having obtained our stores and scientific equipment, we (Mr. J. Stanley Gardiner and Mr. C. Forster Cooper) left England in March 1905 for Ceylon, where we were to join H.M.S. 'Sealark.' Unfortunately, the ship was detained by an accident until May 9, when we weighed anchor, setting a course for Peros Banhos, the large north-west atoll of the Chagos group. On May 14 we reached a latitude south of the Maldives, and commenced sounding, in view of the possible existence of a bank between this group and the Chagos, as indicated by the soundings of the German 'Valdivia' Expedition. We may say at once that our soundings showed a depth of more than 2,000 fathoms between the two groups. The depth increases from the Maldives and the Chagos towards the centre of the passage, and in this position there would seem to be a broad flat, with a depth of 2,000 to 2,150 fathoms. Of course, both east and west, the depth probably increases gradually to 2,500 fathoms or even more, but one obviously cannot build up any views of a possible former connection of the Maldivian and Chagos Banks on such a slender basis.

On our way down we took samples of the sea water and of the plankton (pelagic fauna) at the surface, and at every 25 fathoms to 150 fathoms, using a wire with a heavy weight at the end running over a measuring block, and clamping on the nets as each 25 fathoms ran out. We also took a series of hauls with the Fowler and the Wolfenden closing nets, so as to get our wire into trim, &c. The weather was dead calm with a moderate swell, and generally our results were satisfactory. The Fowler net, being opened at a certain depth, and then hauled up vertically to a lesser depth and closed, seemed more suitable for the conditions prevailing in this region than the Wolfenden, which is opened and closed at the same depth, being dependent on the drift of the ship (in the absence of any deep-sea current) for what enters the actual net; heavy messengers, too, are essential for opening and closing the nets. Of course, these

results on the depth of pelagic animals have a value of their own ; but our best haul, from a collector's point of view, was that of a large net, mouth 1 yard in diameter, length about 12 yards, made of strong mosquito cloth, 8 meshes to the inch. This net we let down on 1,200 fathoms of wire, and hauled in as fast as our winch could take it. Unfortunately, the wire became tied up, but the comparison of the contents of the tin with the collections made by the Fowler net showed that the net itself must have actually sunk to nearly 1,000 fathoms. The presence in the tin of a series of prawns (one 6 inches long), a cuttle-fish, and many strong-swimming jelly-fish, suggests that the use of this method of investigating the swimming fauna (nekton) of the sea should yield valuable results.

The Chagos Archipelago.

On May 19 we anchored in Peros Banhos, but the weather conditions caused us to make Salomon Atoll our first base. We remained there for three weeks, subsequently spending ten days in Peros and a week each in Diego and Egmont, while Commander Boyle T. Somerville and the officers of H.M.S. 'Sealark' carried on surveying work ; we also dredged round Salomon Atoll. Previously there were no bottom soundings between the banks and shoals of the group, but now a large series (more than 100) have been run, showing depths of 400 fathoms to 800 fathoms between the individual banks ; from most of these information as to the nature of the bottom has been obtained.

Broadly speaking, the Chagos group may be said to consist of three atolls to the north (Salomon, Peros Banhos, and Blenheim), the great Chagos Bank in the centre (60 miles by 90 miles), and to the south two atolls, Diego Garcia and Egmont, besides certain submerged banks, both to the north and south. Of these, H.M.S. 'Sealark' re-charted Salomon and parts of Peros Banhos, while Cooper and I, in addition, examined the southern atolls. Salomon was very carefully re-surveyed, our intention being to make a comparison between its condition at the present time and when Powell's chart was made in 1837. The latter chart, however, proved to have been so carelessly drawn that any close comparison is, we think, useless, but the new chart should be of great value when it is possible to re-examine the atoll at some future date. Its section lines show that it rises in the last 400 fathoms by similar slopes to those of Funafuti, but it is a much simpler atoll, having only one passage, and more than half its reef crowned by land. Our numerous soundings and dredgings on its slopes leave no room for doubt but that its present reef is extending outwards on every side on its own talus ; in fact, that the steep found round it (and, indeed, most atolls) is, in this instance, simply the slope at which coral and other remains from the reef above come to rest in the water. Its face was everywhere singularly barren ; *Lithothamnion*, *Polytrema* and, of course, reef-corals were not obtained below 50 fathoms. Further out, at 250 fathoms and over, the bottom was smooth and barren ; the lead constantly failed to bring up any samples, while the somewhat broken and dented but almost empty dredges gave the idea of bare rock with a little muddy sand here and there. Indeed, our evidence points to the impossibility of any upward growth being in progress between the different Chagos Banks, and to the probability of considerable currents being felt even at 500 fathoms.

The reefs of the Chagos are in no way peculiar, save in their extra-

ordinary paucity of animal life. Green weed, too, of every sort is practically absent. However, this barrenness is amply compensated for by the enormous quantity of Nullipores (*Lithothamnia*, &c.), incrusting, massive, mammillated, columnar and branching. The outgrowing seaward edges of the reefs are practically formed by their growths, and it is not too much to say that, were it not for the abundance and large masses of these organisms, there would be no atolls with surface reefs in the Chagos. The lagoon shoals of Egmont are covered by them, and are the only lagoon reefs in the Chagos that reach the surface; having once done so, they die and become hollowed out, finally resembling miniature atolls.

In such a large group as the Chagos the conditions of the encircling reefs against the lagoons naturally vary very considerably. In general their inner edges reach the surface, and in the more open atolls the lagoon slope to 10 fathoms closely resembles the seaward slope. The bottoms of the lagoons are bare rock, hard sand, or mud, with shoals arising precipitously here and there, built up by a few species of coral, but largely covered by *Xenia* and *Sarcophytum* (as are also the only two submerged banks, Wight and Centurion, which we examined). Diego Garcia lagoon differs somewhat owing to its being almost completely surrounded by land. It has, perhaps, the most varied fauna in the group, and gives definite evidence of enlarging in every direction. The land everywhere is entirely of coral origin. Diego Garcia shows signs of a recent elevation of a few feet, the present single island having been formed by the joining up of a series of separate islets on an elongated reef. The kuli, or barachois (large shallow lakes) of the same island owe their origin to the same elevation, though elsewhere in the group they are sometimes due to the successive washing up of beaches from the sea, enclosing areas of the reef. On the whole, there is singularly little change since the survey in 1837, and my impression is that Chagos has been for a long time an area of rest, and that the present condition of its reefs is mainly due to agencies still in action.

We further examined the marine fauna in Salomon, Peros Banhos, Diego Garcia and Egmont, and we would lay stress on its comparative paucity and lack of variety as compared with the Maldives, Fiji and Funafuti, though many of the forms are very common. In short, its general character is rather that of the temperate than of the tropical zone.

The land fauna is largely dependent on the flora, and the latter, except on small isolated islets and selected positions, has been destroyed to allow of coconuts being planted. The shores are everywhere fringed with *Scævola koenigii* and *Tournefortia argentea*, both covered with a climbing bean. Behind these there was originally a forest formed of immense mapou (*Pisonia capidia*) and takamaka (*Calophyllum inophyllum*), with a few coconuts, *Barringtonia*, banyans, and other smaller trees, and an undergrowth largely consisting of immense *Asplenium* and other ferns and *Psilotum*, herbaceous dicotyledons being confined to the more open, dry, sandy and stony parts; mangroves and *Pandani* are, curiously enough, not found. With the assistance of Dr. Simpson we collected the flora of each of the atolls, obtaining more than 600 specimens (about 140 species), of which probably only half are indigenous.

Of mammals there are only rats and mice, but there are traditions of dugong as well. Of birds, the cardinal, sparrow, and mina have doubtless been introduced; noddies, frigates, and terns were breeding in

enormous numbers on certain islands, though it was mid-winter ; crab-plover, curlew, whimbrel and a sandpiper were common, and in the north-west monsoon buzzards, kites, pigeons and crows are said to be regular visitants. The green and shell turtles (*Chelone mydas* and *C. imbricata*) abound, the former coming on shore to deposit its eggs at night, and the latter in the daytime. The only other reptiles are a marsh tortoise, perhaps introduced from Madagascar, and geckoes ; there are no amphibia. There is only one land shell, and arachnids and myriapods are scanty ; the land crustacea are similar to those of the Maldives, but the coco crab (*Birgus latro*) is also abundant. Mr. Bainbrigge Fletcher sorted the insects, and found about 110 species, most of which are probably indigenous, but the best season for the group would be in the rather hotter and damper north-west monsoon. On the whole, the land fauna and flora are much what one would expect to get, regarding the Chagos as a group of purely oceanic islands.

Mauritius.

We arrived at Mauritius on August 5, and remained two weeks, getting certain heavier dredges made, and examining its coasts. The reefs vary from fringing to barrier, the best example of the latter being at Grand Port, where it is four miles from the land. It has there a few small islets of somewhat metamorphosed coral rock, varying up to 40 feet high. At first it seemed as if they might have been formed by hurricanes and blown sand, but we discovered the same rock in the immediate vicinity, overlying a basalt, 70 feet above the water. The present islets probably represent the remains of a considerable island, elevated for at least 100 feet, extending along that part of the barrier reef.

Leaving Mauritius on August 21, we had three days' dredging and sounding off its reefs. The contour is the same as that of atoll-reefs, a gradual slope to 40 fathoms, succeeded by a steep to 150 fathoms, then tailing off in five miles to 1,000 fathoms. The bottom at 150 fathoms was covered with heavy blocks of coral from the reef above. At 300 fathoms we found shell and small pieces of coral, and further out a bottom of bare coral mud, sweepings from the reef and land.

Cargados Carajos.

Between Mauritius and Cargados there was a depth of 1,962 fathoms, there being no marked connecting ridge, though the bottom tails off very gradually from each bank.¹ At Cargados we remained for six days, examining the reefs and islets, and dredging. It is a crescent-shaped surface reef, 31 miles long, on the south part of the Nazareth Bank, which is, roughly, 220 miles long by 60 broad, with an average depth of 33 fathoms. The land is of coral rock with no signs of elevation, and is a great breeding-resort for sea birds. It is covered with guano, owing to which the land flora is very scanty, only 18 different plants being

¹ The Hydrographer, Rear-Admiral Arthur M. Field, informs me that a bank with a depth of about 30 fathoms has been discovered rather to the east of this sounding. It is hence probable that there is a shallow ridge connecting Mauritius and Cargados. Its presence should be shown, too, in the bottom samples between the two localities.

found. Naturally, land animals were scarce, but 42 insects were secured, four-fifths from the guano.

Cooper for the most part took the dredgings, and he reported to me that he found near Cargados 'a wonderfully constant depth of 30-35 fathoms over the body of the bank, while towards its western edge there was a slight but uniform rise to 27 fathoms, thus suggesting an incipient atoll with its eastern side slightly tilted up above its western. Over the plateau, where more than thirty hauls were made in different directions, the bottom was either coral rubble, white sand, shell rubble, or weed. The three latter occurred only in the central parts of the bank, while the coral rubble, though also found there, alone formed the raised edge of the western side, being mostly in the form of large lumps. From this rubble, which is of a bright red colour, due to an encrusting nullipore, we obtained a rich variety of animal life, nearly all forms tinted with red. The absence of living corals from the rim, as well as from the plateau, in all depths over 20 fathoms, was a noticeable feature.' About twenty-five different species of algæ (not lithophytes) were dredged, several from 40-50 fathoms on the outer slope, though none have been secured from more than 60 fathoms.

Saya de Malha Banks.

In the channel midway between Nazareth and Saya de Malha banks we found a depth of 222 fathoms, the connection being a ridge rapidly tailing off on its western side to more than 800 fathoms. Saya de Malha really consists of three banks—a northern, a very large central, and a small south-eastern. The north bank we found to be separated by a channel of 636 fathoms from the central, while the depth between the latter and the southern is only 130 fathoms. All are more or less of the atoll form, but the south side of the central bank differs from all the other parts of the same banks and from the Nazareth bank in tailing off very gradually from 65 fathoms, the general depth in the centre, to 200 fathoms. The area in this part beyond 120 fathoms, which is to some degree protected from the prevailing south-east currents, formed a rich collecting ground, the bottom being composed of a white rubble of bivalve and sea-urchin shells, evidently all swept off the shallower bank above. From 80 to 100 fathoms, where it is more exposed, the bottom is hard, being swept bare by the currents, but still further north, at 60 fathoms, where the eastern edge of the bank has only 10 to 20 fathoms of water, is soft mud with casts of pelagic foraminifera. A considerable number of dredgings were taken at depths above 30 fathoms, and fair collections were obtained. Only the regular deep-living corals were secured, but two hauls at 26 and 29 fathoms gave between them more than twenty species of corals typical of shallow reefs. To the north of the banks we dredged between 300 and 500 fathoms, the bottom being of the usual character at such depths off coral reefs, though with rather more rubble.

Leaving the Saya de Malha, we ran a line of soundings to the shallow bank which surrounds the Seychelles, the greatest depth found being 941 fathoms. Thus our soundings prove the existence of a crescent-shaped ridge, 1,100 miles long, with less than 1,000 fathoms of water, arising on either side from a general depth of 2,200 fathoms.

Coetivy.

We reached Coetivy on September 10, and remained for fifteen days, while the 'Sealark' went to the Seychelles for coal. The island was higher than any we had up to that time visited, having wind-blown sand ridges and hills up to 80 feet above the sea-level, arising on a flat coral reef. Although situated only about 130 miles to the south of the Seychelles Islands, the land fauna and flora are almost the same as on the islands of the Chagos Archipelago, being scarcely richer. The plants, of course, in the main necessarily govern the fauna, and it would appear to us that they are in their turn governed rather by the nature of the soil—coral and coral sand—than by their proximity to continental land. On the other hand, the reefs of Coetivy showed in every group of marine animals a more varied fauna than those of the Chagos, while very nearly all the species of the latter seemed to be present. The reef on the eastern or seaward face of the island was of a rather different character from any we had as yet seen, being covered with *Zostera*. There was also on the same part a considerable variety of algæ, but the edge and outer slope were, as elsewhere, covered by corals and Nullipores.

Farquhar and Providence.

Leaving Coetivy we proceeded to a point about midway between Madagascar and Farquhar Atoll, both to ascertain the depth and the compass variation. The latter was almost the same as at Mauritius, situated 9 degrees to the south, while the depth, 1,856 fathoms, precludes the idea of any close connection between the two localities. Farquhar, which we then visited, was (as, indeed, were all the reefs we subsequently saw) remarkable for its reefs being almost completely covered by *Zostera*, both rim and lagoon. Its land attains a height of 75 feet, and is clearly of the same formation as that of Coetivy; it shows no trace of elevation, and it has not been formed, as has been stated, by submarine deposits.

From Farquhar we proceeded to sound between the chain of islands that extends between Madagascar and the Seychelles, and which would appear to indicate a line of former connection. Between Farquhar and Providence, 32 miles, we found 890 fathoms, and between the latter and Alphonse-Francois, 155 miles, 2,170 fathoms; while there were already soundings of 952 fathoms between Alphonse and the Amirante group, 46 miles, and of 1,150 fathoms between the latter and the Seychelles, 32 miles. As the depth on either side is only about 2,300 fathoms, any connecting ridge is comparatively low and of doubtful importance.

From one dredging at 844 fathoms, 3 miles off the west of Providence Reef, we obtained about 5 cwt. of stones, the largest about 2 feet in diameter, together with some mud. The latter consists practically of volcanic ash, while the stones are of three kinds—(1) manganese nodules, formed round nuclei of ash; (2) consolidated ash; and (3) masses of coral rock coated with manganese. It is clear that the existence of these bottom deposits in such a position will have to be carefully considered in connection both with the formation of Providence Reef and with the existence of any former land between the Seychelles plateau and Madagascar.

Pierre Island, 17 miles to the west of Providence Reef, and with a

depth of 1,088 fathoms between, is peculiar in having no fringing reef. It is simply an elevated coral island, reaching to a height at present of about 30 feet, surrounded by overhanging cliffs, so that landing is extremely difficult. Its rock is entirely coral.

Alphonse and Francois are sandbanks on the rims of two reefs scarcely 2 miles apart. Both reefs are of atoll formation, the lagoon of Alphonse (not shown in any chart) being 3 to 8 fathoms deep and of considerable size.

Amirante Group.

The Amirante Islands are sandbanks, no parts of any being more than 10 feet above the high-tide level. The hills represented in the separate enlarged plans of Darros, St. Joseph and Desroches do not exist, and probably owe their presence thereon to the imagination of the draughtsman.¹ Desroches is really an atoll by itself, lying 10 miles to the east, and being separated by a channel 874 fathoms deep. The rest of the islands and reefs lie on a bank about 50 miles long by 20 miles broad, with an average depth of about 30 fathoms. Eleven separate reefs reach the surface, of which St. Joseph alone has a lagoon, being really a small atoll with about 4 fathoms of water in the centre. With the exception of Eagle, Darros, and Bertaut, all the reefs lie on the rim of the bank, but its edge is in most places covered by at least 8 to 10 fathoms of water. Its slope is steeper than is customary off coral reefs, no possible dredging-ground existing between 60 and 500 fathoms.

All the islands of the Amirante group, with the exception of Marie-Louise and Eagle, are now planted for coconut oil, but the indigenous vegetation still remains in places. The land plants and animals are almost the same as at Coetivy and in the Chagos, the additions due to the proximity of Africa and the Seychelles being relatively few. The marine fauna and flora were markedly richer than even at Coetivy.

Of other work, we took about sixty dredgings off the islands we visited down to more than 800 fathoms, and tow-nettings at various depths to more than 1,000 fathoms. We have, consequently, rich collections, but obviously no estimate of them can be at present formed. We have also serial temperatures in a series of positions, and water samples have been taken throughout down to various depths. Further, magnetic observations have been secured at intervals along the line between Madagascar and the Seychelles.

The Seychelles Archipelago.

We reached Mahé on October 21, and after despatching our collections home we spent eight weeks in examining the group. We camped for eighteen days on Praslin, and then separated, Mr. Forster Cooper being responsible for Silhouette, the fauna of which appeared to have been less collected, while I visited various parts of Mahé and examined its reefs and neighbouring islets. Unfortunately, the weather was exceedingly dry during the first half of our stay, and correspondingly wet during the second half. However, we managed to obtain fairly representative collections of land animals from the endemic jungles, particularly of Mahé.

¹ If we had had any idea of this earlier we should probably have spent our time in visiting Cosmoledo and Aldabra.

The Seychelles Bank comprises about 21,000 square miles within the 100 fathom line, with an average depth of 30 fathoms. Its outer slope is similar to that of the other submerged banks we visited, but a rim is indicated only to the north-west in a series of shallower soundings, 5 to 15 fathoms, and in two typical surface reefs with coral islets, Bird and Dennis. The greater part of the bank appears to be relatively bare, being strongly swept by tidal and other currents. In the centre arises an archipelago of small islands, of which Mahé, Silhouette, and Praslin are the most important, attaining heights respectively of 2,993, 2,467, and 1,261 feet. They together cover about 150 square miles, and are all formed of similar coarse granites, with narrow, vertically extending dykes of finer-grained, black varieties of the same. Many of the bays have flats of sand, largely coralliferous, some washed up from the sea, and others really of delta formation. But in places there is evidence of a recent upheaval of 30 to 40 feet, and in Mahé there are indications of an ancient elevation of about 200 feet.

Barrier reefs nowhere exist around the islands, and fringing reefs only in bays or protected situations, whereas they might be expected to occur everywhere. Examining the coasts, we found a luxuriance of coral growth, but practically a complete absence of nullipores. Indeed, these calcareous algæ are essential in the Indian Ocean for the consolidation of corals into true reefs. Where fringing flats actually occur, they consist of a basis of granitic rock with quite a sparse covering of calcareous matter, or are a filling in with the remains of reef organisms between masses, or islets, of granite and the main islands. Boat passages are the outfalls for the tide, and show no connection with fresh-water streams off the land, beyond the fact that the latter have in many places formed the bays, where they happened to exist. Finally, it is interesting to note that the actual surfaces of the flats are covered with a far greater variety of large seaweeds than we found in any of the purely coral groups we visited in the 'Sealark.'

The Collections, &c.

The collections obtained by the expedition comprise a large series of land and marine organisms, both animals and plants, besides water samples and geological specimens. The waters are in the hands of Mr. D. Matthews, who has also about 2,000 samples collected by various liners in the Indian Ocean; while the crystalline rocks have been undertaken by Mr. Flett, of the Geological Survey. The land and fresh-water animals have been sorted, and so far the following groups have been sent out for determination: Mammalia (Mr. Oldfield Thomas, F.R.S.), Aves (Dr. Gadow, F.R.S.), Reptilia, Amphibia, and Pisces (Mr. G. A. Boulenger, F.R.S.), Mollusca (Mr. E. R. Sykes), Coleoptera (Dr. Sharp, F.R.S.), Rhynchota (Mr. W. L. Distant), Hymenoptera (Mr. P. Cameron), Odonata (Mr. F. F. Laidlaw), Lepidoptera (Mr. Bainbrigge Fletcher), Myriapoda and Arachnida other than spiders (Mr. R. I. Pocock), Acarina (Professor Newmann), Decapoda (Mr. L. A. Borradaile), Chaetopoda (Mr. A. E. Beddard, F.R.S.), Nemertea (Mr. R. C. Punnett), and Turbellaria (Mr. F. F. Laidlaw). The land plants have been undertaken by Mr. J. C. Willis, and the marine algæ (not *Lithothamnion*) by Mr. and Mrs. Gepp.

The sea animals comprise a vast number of forms, both bottom-living and floating. Only the Nudibranchiata (Sir Charles Eliot, K.C.M.G.),

Cephalopoda (Dr. W. E. Hoyle), Pisces (Mr. C. Tate Regan), have so far been sent out, but most groups of bottom-living animals should be ready to place in the hands of specialists before the end of the year. The plankton (pelagic fauna) comprises upwards of six hundred bottles, and has not as yet been sorted in any way.

Arrangements for publication have been made with the Linnaean Society, whereby a series of volumes of its Transactions will be retained for the results of the expedition. During the course of the expedition reports of its progress were published in 'Nature,' vol. 71, p. 562, vol. 72, pp. 341 and 571, vol. 73, pp. 43, 184 and 294; and a longer account of the geography of the Indian Ocean is in the press for the 'Journal of the Royal Geographical Society.'

In addition to the grant from the British Association, the expedition has received financial assistance from the managers of the Francis Maitland Balfour and the Percy Sladen Memorial Trust Funds. Its publications will be associated with the name of the latter trust. It owes the use of H.M.S. 'Sealark' to the Admiralty, and it has been largely aided in many ways by the present hydrographer, Rear-Admiral A. Mostyn Field. All the topographical work was undertaken by Commander Boyle T. Somerville and the officers of H.M.S. 'Sealark,' as well as the observations on magnetics, variation, tides, and temperatures. Mr. Bainbrigge Fletcher, paymaster, assisted in all the land collecting, and is responsible for working out the Lepidoptera. Surgeon Simpson undertook the land plants. In the Seychelles we were largely assisted by his Excellency the Governor (W. E. Davidson, Esq.) in seeing different islands, and by Mr. H. P. Thomasset in land collecting. The expedition, too, met with hospitality and assistance from the managers of most of the islands which it visited.

International Trade Statistics.—Third Report of the Committee, consisting of Dr. E. CANNAN (Chairman), Mr. H. O. MEREDITH (Secretary), Messrs. W. G. S. ADAMS and A. L. BOWLEY, Professor S. J. CHAPMAN, Professor H. E. S. FREMANTLE, and Sir ROBERT GIFFEN, appointed to consider the Accuracy and Comparability of British and Foreign Statistics of International Trade.

THE Committee are now investigating the manner in which inferences drawn from published statistics as to the development of the foreign trade of the principal industrial countries (viz., France, Germany, Great Britain, and the United States) are affected by price changes and alterations in the volume of unrecorded transactions.

If reappointed, the Committee hope next year to report fully on this part of the subject, and to sum up the results of the work already reported upon (see Reports for 1904 and 1905).

Standardisation in British Engineering Practice.
By Sir JOHN WOLFE-BARRY, K.C.B., F.R.S.

[Ordered by the General Committee to be printed *in extenso*.]

IN treating of the subject of Standardisation in Engineering practice, a place of honour must be accorded to Sir Joseph Whitworth, who was mainly instrumental in bringing home to the engineering world the

advantages to be gained by standardisation. The department in which Sir Joseph Whitworth's work took practical shape was in connection with the series of screw-threads introduced by him, which have now come to be regarded as the standard threads almost universally. So advantageous is the existence of standard sizes that the Whitworth series, though based on the inch, is largely used even in countries where the metric system is in vogue. Sir Joseph Whitworth's favourite illustration when urging the necessity for standardisation was that of candles and candlesticks, which came home in the early eighties to every user in a way which it may not do in the present day, when so many of us are accustomed to light our rooms by merely turning a tap or a switch. Sir Joseph Whitworth says: 'Candles and candlesticks are in use in almost every house, and nothing could be more convenient than for the candles to fit accurately into the sockets of the candlesticks, which at present they seldom or never do.' The lesson taught by his illustration lies at the root of standardisation, and necessarily carries with it the restriction of the few for the advantage of the many. Broadly speaking, there is no reason why the candle-maker should not make the ends of his candles to any design and shape which may be most convenient to himself, and the candlestick-maker can adopt any form of socket in his candlestick which he may desire, but obviously the multiplication of sizes and shapes of candles and sockets is not to the advantage of the general user, while a restriction to a sufficiently wide range of sizes to suit all practical purposes is beneficial to the user, and consequently must result ultimately to the advantage of the manufacturer. The principle underlying the above homely illustration is applicable to all engineering practice, and lies at the root of the work which the Engineering Standards Committee has been formed to carry out.

The opposition Sir Joseph Whitworth met with in many quarters from those who thought that the maintenance of some particular form of screw-thread would ensure customers returning to them for repairs, &c., is well known, and it was some years before the series of threads introduced by Whitworth could in any sense be said to have been universally adopted as standards.

Formation of the Engineering Standards Committee.

It had been felt of late years that a great waste of time and money was occurring in the rolling-mills throughout the country by the use of an unnecessary number of varying sizes and shapes of angles, channels, tees, bars, rails, &c. The want of some recognised and important body to lay down authoritative standards was emphasised on my mind by some remarks made by Lord Salisbury in his reply to the deputation, of which I formed one, who waited upon him at the Foreign Office in February 1897 to urge the establishment of the National Physical Laboratory.

Inquiries among engineers and manufacturers of steel convinced me that though there was not complete unanimity, there was a great preponderance of opinion that it was high time in the interests of the nation, as also of the manufacturers, that an effort should be made to simplify and economise the cost of production. The need of some action to lay down authoritative standards, at least in manufactured steel, was, amongst other similar communications, forcibly expressed in a letter received by me in 1900 from the chairman of one of the chief steel works

in Scotland, Mr. John Strain, and I was gradually led, both on general lines as well as by particular instances, to suggest in January 1901 to the Council of the Institution of Civil Engineers that a Committee be appointed to consider forthwith the advisability of standardising in the first instance various kinds of iron and steel sections. My motion was carried, and the original Committee consisted of seven members—viz., Sir Benjamin Baker, Sir Frederick Bramwell, Sir Douglas Fox, Mr. James Mansergh, Professor Unwin, Mr. J. A. McDonald, and myself, all of whom were Members of Council of the Institution of Civil Engineers. At their first meeting, in February 1901, the late Mr. James Mansergh, who was then President of the Institution of Civil Engineers, was appointed Chairman, which post he occupied till his lamented death in 1905, and Dr. Tudsbury, Secretary of the Institution, was nominated as Hon. Secretary.

It was decided at this Meeting to recommend that the Council of the Institution of Civil Engineers should not attempt to deal with so far-reaching a matter alone, but that the Institution should approach the Councils of the Institution of Mechanical Engineers, the Institution of Naval Architects, and the Iron and Steel Institute, inviting them to nominate members on the Committee. This invitation was accepted, and the Committee thus constituted met for the first time in April 1901. Mr. Leslie Robertson was appointed as Secretary, and to his indefatigable exertions the movement is very greatly indebted.

At a later date it was decided to enlarge the reference to the Committee, and the Institution of Electrical Engineers was invited to co-operate with the other four Institutions, which invitation they accepted. Thus constituted, and supported by the five leading Technical Institutions, the organisation has gradually grown from one Committee with seven original members till at present it numbers thirty-six Committees with about 260 Members, and the number of subjects already dealt with has increased from the original matter of the standardisation of iron and steel sections to no less than thirty different subjects, entailing the preparation of about seventy-five different Specifications and Reports.

The whole work is controlled by what is known as the Main Committee, which is composed of the representatives of the five Institutions referred to above, and to this Committee falls the entire organisation of the work, the raising of the necessary funds, the controlling of the expenditure, the arranging of the subjects to be dealt with by the various Sectional and Sub-Committees, and the passing of all Reports prior to publication.

Under the Main Committee there are twelve Sectional Committees appointed by the Main Committee, and twenty-four Sub-Committees appointed by the Sectional Committees.

In the initial stages the funds necessary for carrying on the work were supplied entirely by the supporting Institutions; but it was recognised at an early date that the support and countenance of His Majesty's Government would be invaluable to the movement, and also that the various Government Departments, who were large users of the materials for which standards were being drawn up, should be asked to support the Committee by nominating representatives to assist in their deliberations, and to arrange for the adoption of the Committee's standards when issued. With this object the Committee approached His Majesty's Government, and at the instance of Mr. Arnold Forster (then Parliamentary Secretary to

the Admiralty), who gave the movement cordial assistance, an interview was held with Mr. Balfour, who accorded the Committee a most favourable reception, and stated that he was convinced that the public advantages of standardisation were so great that no one could have any doubt of the importance and magnitude of the movement. He intimated that the financial support sought by the Committee would be forthcoming. Further, that the findings of the Committee would, as far as possible, be adopted for use in the Government Departments, which would at once appoint on the various Committees engineer officers as their representatives.

Subsequently a deputation was requested to wait upon the President of the Board of Trade in regard to the definite financial support of His Majesty's Government, and as a result of this interview the Treasury included a sum of 3,000*l.* in the Estimates for 1903-4 as a contribution to the funds of the Committee for that year. At a later date they agreed to extend their financial support over the two following years by giving the Committee a grant-in-aid equal to the amount contributed by the supporting Institutions, manufacturers, and others. They have since agreed to continue the grant on a reduced scale to the end of the financial year 1908-9. The view of the Government was that though standardisation deserved their support as large consumers, and from the point of view of its being a national matter in the competition of this country with foreign nations, it was also very distinctly to the private advantage of individual manufacturers as producers, and they rightly made it a condition and measure of their support that manufacturers and private companies as large consumers should also provide financial assistance.

The leading manufacturers, railway, and other companies who it was felt would be materially benefited by the work of the Committee were accordingly asked to assist the Committee not only in the nomination of gentlemen to serve on the various Committees, but also to contribute towards the finances required to carry on the work, and to this appeal a liberal response has been received.

The Indian Government has made a grant of 1,000*l.* towards the general expenses of the Committee in recognition of work done in the interests of that country, and especially in regard to the report on the Standardisation of Indian Locomotives, which received the approval of the Secretary of State for India.

The Secretary of State for India in Council has since asked that the Locomotive Committee may be made a permanent body, for the purpose of considering questions remitted to them from time to time by the Railway Board in India. To this request the Main Committee has acceded, and the Indian Government has undertaken to defray the expenses incurred by the Committee in the preparation of reports on any subjects affecting India remitted to the Committee.

Though in this country we are not so liberal in the support accorded to scientific investigations as some foreign Governments are, yet the financial support accorded to the Committee by the British Government, as also the recent extension of their grant to the National Physical Laboratory, form a worthy illustration of how the financial support of an enlightened Government can be used to foster movements which redound to the good of the community at large.

Constitution and Method of Procedure.

As far as possible the Committees have been so constituted as to embrace among their number representatives of all interests involved—the Government Departments, the consulting engineers, manufacturers, users, contractors, and purchasers. It has thus been practically ensured that those serving on the Committees can speak with full knowledge and authority on the subjects dealt with.

In order to obtain the necessary information upon which to base their decisions, and to have access to a wider source of information than would be available were it restricted to Members serving on the Committees, carefully prepared lists of questions for circulation to users and manufacturers throughout the country have, in many cases, been issued, and the replies to these questions have been collated. On the results of these inquiries the Committee's decisions are largely based.

In a number of instances the Committee have not been content with written replies, but have invited before them representatives of the trades concerned, in order to obtain evidence in greater detail; and in some instances meetings of a more public nature have been convened by the Sectional Committees in order that a more widely expressed opinion may be obtained on different points under discussion.

The specifications are usually, in the first instance, drafted by a Sub-Committee appointed by each Sectional Committee, and when completed are sent up to the Sectional Committee for their careful consideration. All Specifications, after passing the Sectional Committees, have farther to go before the Main Committee prior to their publication. By this means the labours of the various Committees are correlated, hasty legislation is avoided, and as far as possible the best interests of user and producer are safeguarded.

It was felt from the first that a most important point in any proper scheme of standardisation was to avoid the danger of either crippling invention or perpetuating forms or processes which in course of time might become obsolete. Accordingly it was recognised in the first motion made at the Institution of Civil Engineers that there must be provision for a continuance of the existence of the body which might be formed to take the original standards in hand. It was not enough to standardise the most approved forms and processes of manufacture, but it was urgently necessary to provide for future improvements.

To carry out this view the Main and Sectional Committees continue in existence after their reports have been made, and an opportunity is afforded once a year to the Sectional Committees of revising the Specifications issued by them. This ensures that the Standard Specifications are kept thoroughly in line with the progress made from time to time in engineering science, and that there is no stereotyping of design or practice.

Standardisation of Shape and Form.

Standardisation may roughly be divided into two classes—that dealing with shape and form, and that dealing with material. In regard to shape and form, the guiding principle of the Committee has been to place at the disposal of the engineer such shapes and sizes as may reasonably be needed by him to meet the general requirements of everyday work, and they

have carefully avoided indicating to the engineer how and when these shapes should be used, or what particular strains should be allowed in the material composing them. The Committee have felt that this is a question entirely for the engineer, and that he alone must decide what stresses may be allowed in the structures which he is engaged in designing.

In one instance only have they departed from this principle, and that at the special request of the Secretary of State for India, who desired them to design certain specific types of locomotives for use on Indian railways, which it will be remembered, unlike the railways in this country, are under direct Government control.

To give an illustration of the graduation in the standardising of shapes and forms, it may be mentioned that the Committee have laid down sixteen sizes of equal angles, thirty of unequal angles, twenty of bulb angles, six of bulb tees, seven of bulb plates, eight of Z bars, twenty-seven of channels, thirty of beams, and twenty of tees. In the case of railway rails there are, advancing by 5 lb. at a time, nine sizes of bull-headed rails from 60 lb. to 100 lb. per yard, seventeen sizes of flat-bottomed rails from 20 lb. to 100 lb. per yard, and five sizes of tramway rails from 90 lb. to 110 lb. per yard. Five corresponding sections of tramway rails, having a wider groove for use on curves, have also been designed.

Standardisation of Material.

When the Committee commenced its labours it was not the intention to deal with the standardisation of material, but it soon became evident that assistance of a very real character could be rendered to the manufacturers of this country if high-class Standard Specifications were issued, covering the materials more generally used in engineering.

The multiplication of various Specifications for the same subject, differing from one another often in unimportant details, but yet sufficiently divergent to preclude the unification of the process of manufacture, was a widely experienced difficulty, and one which the Committee sought, by the issue of Standard Specifications, to remove. It was felt that if a high-class Standard Specification were generally acknowledged, it would inevitably tend to improve manufacture and assist British manufacturers to meet competition.

Advantages of Standardisation.

The advantages accruing from the work which has been accomplished are now so familiar that we hardly realise their extent, and may be tempted to minimise their value.

It must, of course, be borne in mind that every advantage is accompanied in a lesser or greater degree by some disadvantage. For instance, should standardisation be pushed too far, it might in some instances stereotype design or retard the progress of invention; but provided that it is clearly understood that special circumstances must exist which warrant special designs, and as long as standardisation is confined to broad principles and the standards laid down are sufficiently numerous, the advantages must immeasurably outweigh the disadvantages. Exceptional cases may no doubt exist, for instance, where the use of some particular form of angle or channel is justified, and where the expense entailed in cutting special rolls, and delay in manufacture by the consequent chang-

ing of rolls, is warranted ; but in the vast majority of cases an engineer can equally well use standard sizes without in any way cramping or impairing his design.

In the case of steel, standard sizes are undoubtedly very valuable to trade, as they avoid the necessity of cutting new rolls ; they can be rolled to stock, thus obviating any interruption in process of manufacture and minimising delay in delivery. As a practical illustration the testimony of a large steelmaker in Scotland may be cited, who states that since the introduction of standard sizes his firm has been able to break up some hundreds of tons of rolls, and also that by no means the least advantage gained is that in his works the process of manufacture is now no longer constantly interrupted as it used to be, by the frequent changing of the rolls to produce in smaller quantities the many special sizes asked for, without any corresponding advantage to the consumer.

Another definite illustration of the advantages of standardisation occurred in connection with the construction of the tramways of a large Midland city. An order for the rails (to be made in conformity with the British Standard Specification) was, in the first instance, placed with a Continental firm. From want of expedition and punctuality in making deliveries, and from failure to comply with the stipulated tests, &c., the Corporation and their contractors were placed in a position of considerable difficulty by the constructional work being brought to a standstill. This caused them to approach a British firm, who, having the 'standard' rolls already cut, undertook to make a delivery within a few days, with the result that the Continental order was cancelled and transferred to the British firm.

Altogether orders have already been received for nearly 100,000 tons of these standard rails, probably representing a value of over half a million of money. Practically all the British firms of tramway-rail makers are now equipped with sets of rolls for the standard sections, and they are thus enabled to deliver such rails at very short notice, instead of the general experience heretofore of having to spend several weeks in the preparation of new rolls. This is not only a great advantage to the purchaser, but also a considerable saving in expenditure to the maker, as the cutting of a set of rolls usually costs about 200%.

The best interests of the community at large must certainly be served when articles of acknowledged and universally used sizes can be produced with the minimum amount of expenditure and with the least possible delay in delivery.

Apart from its general influence on the expansion of trade, it is estimated that there will be a saving of some millions sterling to British manufacturers in reduction of cost of production by the standardisation of iron and steel sections alone.

Mention may be made of the work accomplished by the Sectional Committee on Screw Threads and Limit Gauges, which have confirmed the shape and form of threads originally devised by Sir Joseph Whitworth, and have added to his series of somewhat coarse pitches a finer series of pitches suitable for parts of machinery subject to vibration, &c., and more calculated to meet the recent advances in engineering practice. They have further embodied in their findings the series of fine threads decided upon by the Committee of Section G appointed by the British Association some years ago.

It will be a satisfaction to this Meeting to realise that the work first

voluntarily undertaken by the British Association, has now become one of the standards of the Empire.

With a view of introducing standardisation in its most efficient and stable form the Committee have decided to establish at the National Physical Laboratory at Bushy a series of gauges and templates to which all the templates throughout the country can be referred, and from time to time checked. Thus they have already created a standard series of templates for bull-headed and flat-bottomed railway rails, tramway rails, and pipe flanges, and are hoping to add at no very distant date standard gauges for screws, both with the ordinary Whitworth pitch and the finer pitch referred to above. All these standards are made with the greatest possible accuracy, and are most carefully verified by measuring instruments at the laboratory before acceptance.

Mention might also be made of the research work which the National Physical Laboratory have accomplished at the request of the Sectional Committee on Electrical Plant, with regard to insulating materials generally, the temperature rise in the field coils of electrical machinery, and the efficiency of glow-lamps.

Owing to continuity of existence, we have now in the British Engineering Standards Committee a body to whom engineers and manufacturers can refer when they desire that subjects for standardisation should receive consideration. It is also distinctly representative, drawing its Members from all parts of the kingdom, and from every section of those affected.

Though less apparent at first sight, perhaps one of the main advantages of the appointment of the Standards Committee has been the fact that it has provided an impartial tribunal of a very high technical order, where conflicting interests, often of large importance and involving considerable financial considerations, can be thoroughly and amicably discussed. The accredited representatives of the various industries are certain of obtaining a patient hearing, and where divergent interests have to be reconciled, of arriving at a compromise best suited to meet the needs of both parties concerned.

A fact which I should like to touch upon before closing is the willing and gratuitous services rendered by the gentlemen of the highest position in their various professions and trades, who serve with the greatest zeal and self-devotion on the various Sectional Committees and Sub-Committees. To attend the Meetings of the Committees they frequently have to travel long distances, and devote very much time, entirely at their own charges. I desire to bear testimony here to the invaluable services so ungrudgingly rendered in the interest of Standardisation by those serving on the various Committees.

It is impossible, of course, within the limits of this short paper to do more than roughly indicate the extent of the Committee's operations, but sufficient has, I think, been said to justify the initiation and existence of the Committee by the growth of the demands made upon it, and the advantage which it has been able to confer upon those for whom its findings have been drafted.

Considering the short time which has elapsed since the issue of the first Standard Sections and Specification, the success of the movement has been most marked and beneficial. It may be confidently predicted that the future effect of the movement will be greatly to the benefit of the nation.

Anthropometric Investigations among the Native Troops of the Egyptian Army.—*Report of the Committee, consisting of Professor A. MACALISTER (Chairman), Professor C. S. MYERS (Secretary), Sir JOHN EVANS, and Professor D. J. CUNNINGHAM.*

A FURTHER paper prepared by the Secretary is now ready for publication in the 'Journal of the Anthropological Institute.' The measurements, which were published in the last Report to the British Association, have since been studied in greater detail. The probable errors of the means have been calculated, and have been taken into account in comparing the population of different provinces in respect of eight characters.

The conclusions drawn are :—

- (i) that while the differences in cephalic index which occur between the people of Daḳahlia, Ḳena, and Girga are not with any certainty significant, the people of Daḳahlia are with considerable probability distinctly less dolichocephalic than the people of Giza and Baheira ;
- (ii) that the differences in mean facial index for the various provinces are not with certainty significant ;
- (iii) that a most marked difference in the nasal index occurs in the various provinces, as shown in the following table :—

Province	Nasal Index	Province	Nasal Index
Ḳena	78·90	Fayum	77·61
Girga	77·77	Giza	75·33
Assiut	78·01	Baheira	74·39
Minia	77·38	Gharbia	73·98
Beni-Suef	77·61	Daḳahlia	73·41

Omitting for the present from consideration three provinces of Lower Egypt, Menufia, Ḳaliubia, and Sharkia (in two of which the number of individuals examined was certainly insufficient), we see that a very decided fall occurs in the nasal index, as we descend from Upper to Lower Egypt.

These variations in the nasal index appear to be accompanied by similar changes in the gnathic index. Thus, on the whole, the people of Lower Egypt are distinctly more leptorhine and apparently more ortho-nathous than those of Upper Egypt.

Two characteristically negroid features, a relative increase in the length of the tibia and of the radius, are probably somewhat more marked in the provinces of Upper than in those of Lower Egypt. However the small number of measurements of these characters and their wide variability compel us to accept this conclusion with reservation.

A study of the average homogeneity of the population as determined by the coefficients of variability fails to show the existence of any difference in this respect among the peoples of different provinces.

The distributions of individual measurements which have been investigated relate to the (i) head length, (ii) head breadth, (iii) cephalic index, (iv) nasal length, (v) nasal breadth, (vi) nasal index, and (vii) upper facial index for the following provinces : (a) Ḳena and Girga, (b) Assiut and Minia, (c) Gharbia, (d) Daḳahlia, (e) Menufia.

Alike in *all five* frequency polygons of the nasal index, a peak is shown

at 72 and another at between 76 and 78. In the frequency polygons of nasal length, they *all* show a peak at 46-47, and another at about 50. In the polygon for nasal breadth the provinces of Ḳena and Girga show a single peak at 37, those of Assiut and Minia, Gharbia, Dakahlia, and Menufia, show a peak at 35-36, while those of Assiut and Minia, Gharbia and Menufia, show a second peak at 38.

The frequency polygons of the cephalic index for Assiut and Minia and for Dakahlia show one peak at 73 and another at 77, that for Ḳena and Girga shows one peak at 73 and the other at 76. Those for Gharbia and Menufia show a single peak at 74.

It is tempting to suppose that some, at least, of these coincidences cannot be due to chance, and that the distribution curve is a composite of two (or more) elementary constituents, each of which has a single peak, and constitutes an underlying ethnic type. Further statistical examination is in progress to test the probability of this supposition.

Lastly, a study has been made of those differences of form, colour, and texture of certain regions of the body, the grades of which it is difficult or impossible to express numerically. Tables have been prepared showing for different provinces the percentage frequency of different grades in (1) eye colour, (2) skin colour, (3) hair colour, (4) hair texture; the shape of (5) chin, (6) lip, (7) root, (8) bridge, (9) alæ of nose; (10) development of the lobe of the ear, (11) shape of the head in *norma occipitalis*.

The skin and eye colour lightens in the more northern provinces; the hair colour is remarkably uniform. Spiral and crisp hair is relatively more frequent in Upper Egypt, curly and wavy hair in Lower Egypt. The chin shows no obvious difference.

The lips become more delicate as we proceed further north. A study of the nose shape corroborates the conclusions already reached by calculations from the nasal index.

The remaining features utterly fail to serve as differentiating characters.

We conclude, then, that the most important difference between the inhabitants of different provinces, which is revealed by our anthropometric survey, lies in the relative prominence of negroid features as reflected in the nasal and gnathic index, the form of the nose, the colour of the eyes and skin, and the texture of the hair.

We have yet to consider certain special problems; *e.g.*, measurements on the Copts, on the inhabitants of the Fayum oasis, on the Sudanese, and on individuals of mixed parentage. But in order to effect this (which will form the conclusion of the inquiry), the Committee does not seek reappointment.

The Committee is strongly of the opinion that for future reference the fifteen thousand Egyptian measurements and the Sudanese measurements which have been accumulated in this anthropometric survey should be published in the pages of the 'Journal of the Anthropological Institute,' where the details abstracted in these reports have already appeared. The data are capable of considerable further study, and may be put to very different uses according to the interest and needs of later investigators. The Committee is very glad to learn that the Council of the Anthropological Institute has consented to pay one half the cost of printing these data, from the funds of the Institute.

Anthropometric Investigation in the British Isles.—Report of the Committee, consisting of Professor D. J. CUNNINGHAM (Chairman), Mr. J. GRAY (Secretary), Dr. A. C. HADDON, Dr. C. S. MYERS, Mr. J. L. MYRES, Professor A. F. DIXON, Mr. E. N. FALLAIZE, Mr. D. RANDALL-MACIVER, Professor J. SYMINGTON, Dr. WATERSTON, Sir EDWARD BRABROOK, Dr. T. H. BRYCE, Dr. W. L. H. DUCKWORTH, Mr. G. L. GOMME, Major T. McCULLOCH, Dr. F. C. SHRUBSALL, Professor G. D. THANE, and Mr. J. F. TOCHER.

THE Committee, in fulfilment of a promise made in the last report, now publish illustrations of the adult male human figure upon which are marked the points between which dimensions are to be measured. These illustrations have been prepared by the Chairman (Professor D. J. Cunningham), with the assistance of Dr. D. Waterston, from the living model. The external points are shown on photographs of the model, on which they had been marked before the photographs were taken. The points on the skeleton corresponding to the surface marks on the photographs are shown by diagrams placed opposite, and the name of each point is indicated by text surrounding the illustrations. These diagrams, it is considered, will be of great value as a supplement to the definitions of the anatomical points given in the last report.

A list of psychological characters has been prepared and is published herewith. For this list, with the directions which accompany it, the Committee have to thank Dr. W. McDougall, Wilde Reader in Mental Philosophy in the University of Oxford. Dr. McDougall, while recognising the great value of psychological data obtained by methods which give consistent results, wishes it to be stated 'that, in view of the difficulty of the project, any issue of such circular should first be undertaken, in an experimental spirit, to certain few selected schools only, with a view (1) to see whether trustworthy results may be hoped for, (2) to improving the list of characters, and of instructions to teachers. The former object would be best served by getting two or more teachers in several schools to fill up cards for the same pupils, independently of one another.'

Dr. McDougall wishes the list to be considered for the present provisional, and before it is actually issued for observations that it should be submitted for criticism to a number of experienced teachers in training colleges and so forth.

The list is now published here with the view of obtaining the assistance of experienced teachers and others in this experimental testing of the possibility of making reliable observations. The results of the experience gained in this way will be embodied in the final instructions in anthropometry, which it is proposed to issue in separate form.

A provisional schedule has been prepared, which is specially adapted for registering observations on schoolchildren, but which may also be used for adults. Criticisms of this provisional schedule are desired.

The schedule consists of one or more cards enclosed in an envelope. One card is used for each age at which the child is measured. On the

front side observations on anatomical, physiological, and psychological characters are recorded ; on the back are recorded factors of the environment, the results of medical inspection, and miscellaneous data that may be of interest. On the face of the envelope containing the cards are recorded the name, birthplace, and other more or less permanent data, also the numbers of schedules of any relatives of the subject who may have been measured. Such entries will render it possible to institute comparisons between members of the same stock reared under different environments, and, as the records accumulate, to form tables (correlation tables) illustrating the intensity of the resemblance between relatives.

The Committee have not been able this year, as proposed in last report, to publish anything on the subject of instruments. They hope, if re-appointed, to deal with this subject next year.

The Committee hope also to prepare at an early date a book of instructions in anthropometry, which would be available to teachers and others, to enable them to make measurements and enter them in the schedules. The anatomical illustrations prepared by the Chairman would be made use of in these instructions. The Committee is considering whether this code of instructions should be issued in a form suitable for inclusion in the next edition of the Association's 'Notes and Queries in Anthropology.'

The Committee proposes further to draw up instructions for photographing typical examples of the population in different localities, and to illustrate the methods proposed by a practical instance.

A meeting of the Sub-Committee was held at the Anthropological Institute on October 9 last.

The Committee have again to thank the Anthropological Institute for providing them with headquarters and granting permission to hold meetings in their rooms.

The Committee desire to be re-appointed, with instructions to continue the work indicated in the above report ; and, if so re-appointed, ask for a grant of 15*l.*, in addition to an unexpended balance of 7*l.* 17*s.* 3*d.* left over from the grant of last year.

APPENDIX.

PROVISIONAL SCHEDULE FOR CRITICISM.

1. *Front of Card.*

Name _____ Age _____ No. _____
Place of Observation _____ Signature of Observer and Date _____

ANATOMICAL CHARACTERS.		PHYSIOLOGICAL.	PSYCHOLOGICAL.
(A 1)		(1)	(1)
(A 2)		(2)	(2)
(A 3)		(3)	(3)
&c.		&c.	&c.

2. *Back of Card.*

ENVIRONMENT.	RESULTS OF MEDICAL INSPECTION.
(1)	
(2)	
(3)	
(4)	
(5)	
(6)	
(7)	MISCELLANEOUS DATA.
(8)	
(9)	
(10)	

3. *Face of Envelope.*

ANTHROPOMETRIC SCHEDULE,

No. _____

Surname and Christian Names (in full) _____

Sex _____

Birthplace _____

Date of Birth _____

Father's Birthplace _____ *No. of Schedule* _____

Mother's Birthplace _____ *No. of Schedule* _____

Brothers : Nos. of Schedules _____

Sisters : Nos. of Schedules _____

Cousins (first) : Class and Nos. of Schedules _____

Uncles : Class and Nos. of Schedules _____

Aunts : Class and Nos. of Schedules _____

Grandfathers : Class and Nos. of Schedules _____

Grandmothers : Class and Nos. of Schedules _____

The same number will be written or stamped on all cards and their envelope which relate to the same subject or person measured.

As many cards as are required are used, care being taken to note the age of the subject and the date of the observations.

The symbols under 'Anatomical Characters' refer to the list of anatomical characters published in the last report.

PSYCHOLOGICAL OBSERVATIONS.

Instructions to the Observer.

Mental characters are named, numbered, and briefly defined in this sheet of instructions.

The accompanying card bears a corresponding number of numbered spaces.

The observer should put the name of one subject (child, &c.) at the head of each card, and then put in the space opposite each number one of the letters A, B, C, D, or E.

These letters imply the following opinion on the part of the observer in respect to the mental characters of corresponding numbers :—

C is to be used to imply an average degree of development, intensity, or strength of the character in question.

B, a degree of development distinctly above the average.

D, a degree of development distinctly below average.

A, very exceptional degree of development.

E, very marked deficiency of the character.

An average degree of development is to be taken to mean such as would be exhibited by about 50 per cent. of any large number of normal subjects (children, &c.) of the same race or class, this 50 per cent. group being made up of those who in respect to this character are nearest the mean.

Classes B and D should contain about 20 per cent. each of any large number of normal subjects.

Classes A and E, about 5 per cent. each.¹

The observer should fill in on each subject card only those characters in regard to which he feels able to express a confident opinion, and should leave all other spaces blank.

The words in popular usage by which mental characters are described are in many cases of a negative character. In the following list such words have been avoided and positive characters only are named; *e.g.* selfishness does not appear, because a high degree of selfishness is the same character as a low degree of generosity, and may be expressed by putting the letter E after the corresponding number.

Many of the words in popular usage express characters which are extremely complex resultants of a number of more elementary characters (*e.g.* intelligence); such words have been avoided as far as possible, and the characters named below have been chosen as being relatively simple and elementary.

List of Mental Characters.

1. *Accuracy and fulness of sense-perception (i.e. power of 'observation in general).*

2. *'Quickness' of apprehension in general.*

¹ It may be helpful to explain the foregoing in other words, thus: Suppose an array of 100 normal children arranged in order of the intensity or strength of the character in question, No. 1 being the highest and No. 100 the lowest, the Nos. 1-5 rank as A; 6-25 as B; 26-75 as C; 76-95 as D; 96-100 as E.

It is desirable that a separate description should be given of each character in the midway or average child in each class or school, with a view to comparison with the average in other classes and schools.—*Secretary's note.*

3. *Scope of apprehension* (*i.e.* capacity of apprehending complex relations and multiplicity of detail).

4. *Intensity of application* to mental tasks (*i.e.* power of concentrating the attention ; this may be taken to be inversely as the readiness with which attention is distracted by irrelevant objects and impressions):

- (a) Spontaneous or non-voluntary.
- (b) In virtue of effort of will.

5. *Capacity of sustained application* (*i.e.* of sustaining and repeating concentration of attention upon given tasks = 'perseverance'):

- (a) Spontaneous.
- (b) In virtue of effort of will.

6. *Width of field and intensity of natural or spontaneous interests* (*i.e.* natural keenness upon a wide range of topics, or great keenness upon some few topics, or upon one only—intensity of interest being taken as compensatory to restriction of the field, and *vice versa*).

7. *Native 'retentiveness' of memory*, expressed by accurate retention of facts sporadically acquired or committed to memory by rote learning.

8. *Systematic and selective memory* (*i.e.* retention of facts in virtue of the apprehension of their connection with some topic of special interest to the subject).

9. *Freedom and range of play of fancy* (*i.e.* in popular speech—'imaginativeness').

10. *Vividness and detailed accuracy of representative imagination* (*i.e.* power of recalling past sense-impressions in corresponding imagery).

11. *Constructive imagination* (*i.e.* inventiveness, or the power of bringing things together in imagination in relations in which they have not previously been experienced).

12. *Power of 'logical inference.'*

13. *Confidence in own observations and inferences and judgments* (*i.e.* the reverse of 'suggestibility').

14. *Excitability in general*, including susceptibility to emotional disturbances of various kinds.

15. *Sympathy* (the tendency to be moved by an emotion when the expression of it in another person is witnessed, *i.e.* primitive sympathy).

16. *Generosity* (the tendency to place the welfare of others, individuals or the public, before one's own as a motive to action—the reverse of selfishness).

17. *Conscientiousness* (tendency for actions to be controlled by general principles rather than by the immediate promptings of desire and emotion—expressed, *e.g.* in truthfulness, honesty in schoolwork, punctuality, and general trustworthiness).

18. *Sensitiveness to opinion of others, or to public opinion* (this is not to be confounded with conscientiousness or with suggestibility).

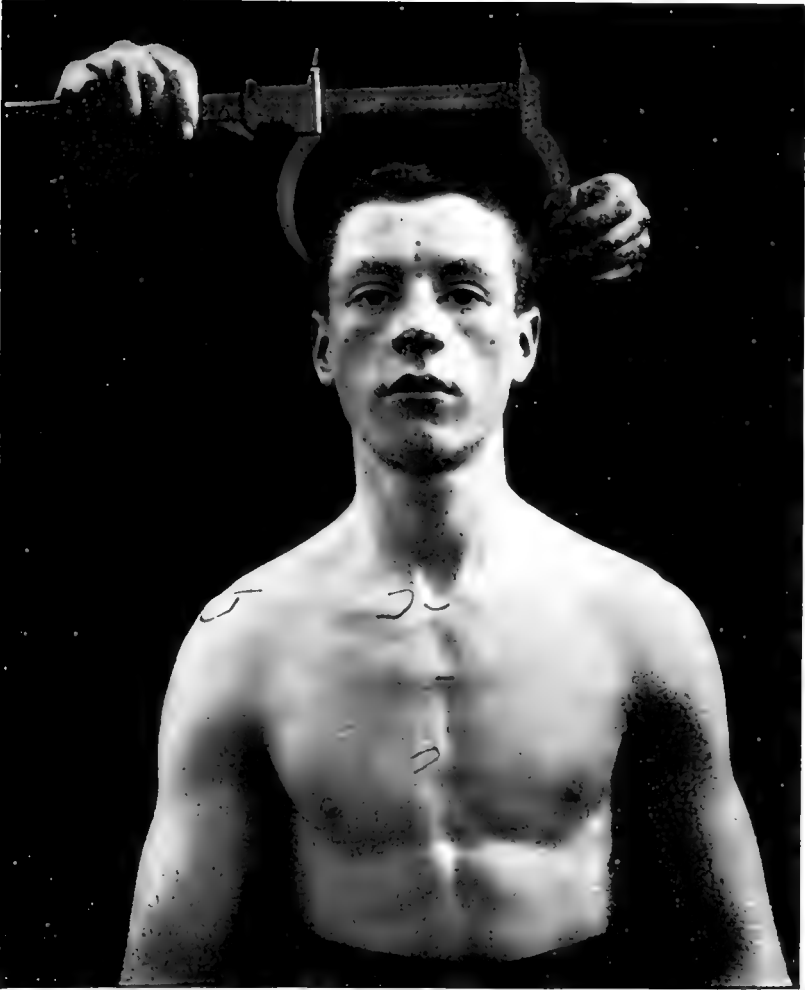
19. *Sociability* (the finding of pleasure and satisfaction in the society of fellows).

20. *Independence and initiative* (expressed, *e.g.* in tendency to assume leadership in games, in class, &c.).

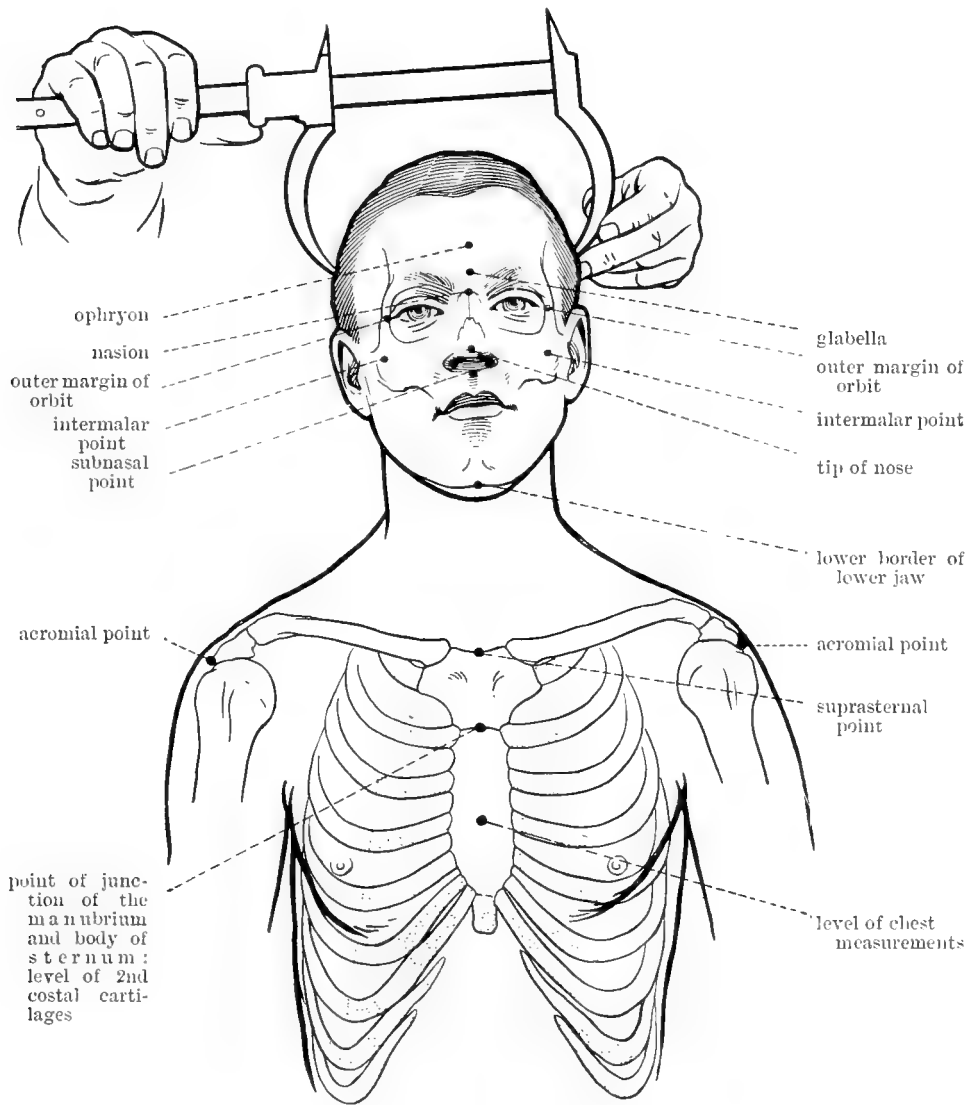
21. *Competitive or emulative spirit.*

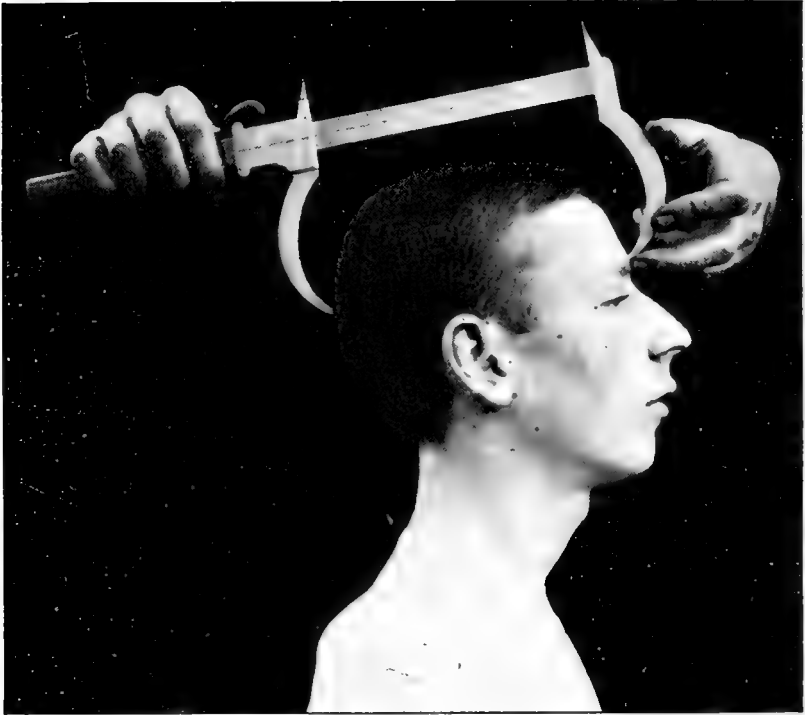
22. *Energy* (*i.e.* capacity for doing work without exhaustion).

NOTE.—The words in inverted commas may be used as catchwords for the corresponding classes.



Front View of Head, Chest and Shoulders (Cunningham).





Profile View of the Head (Cunningham).

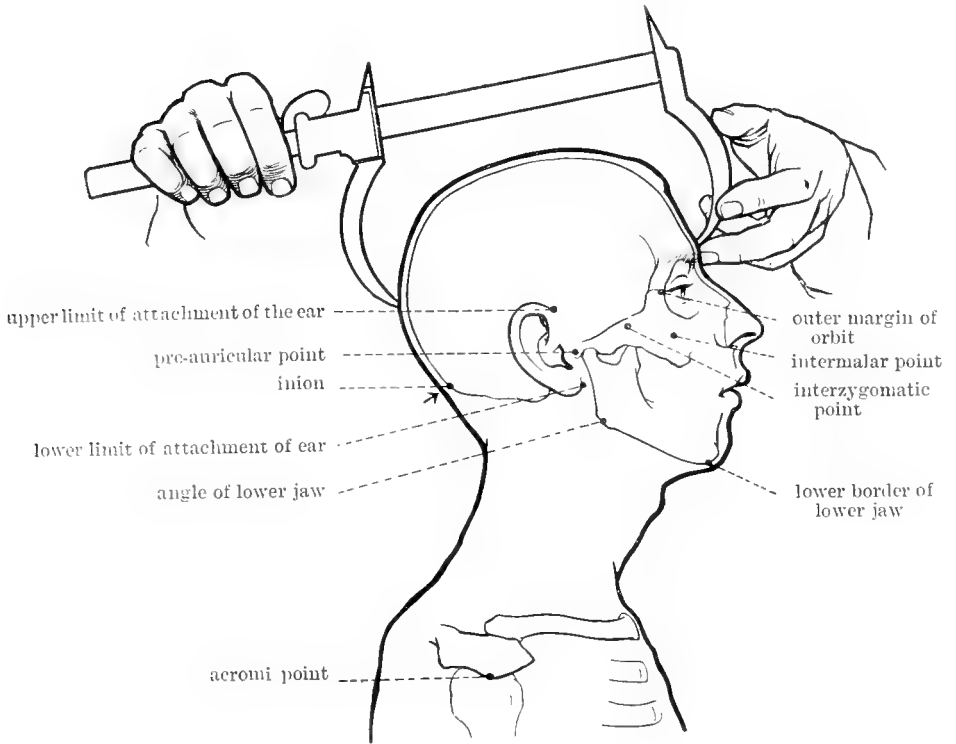
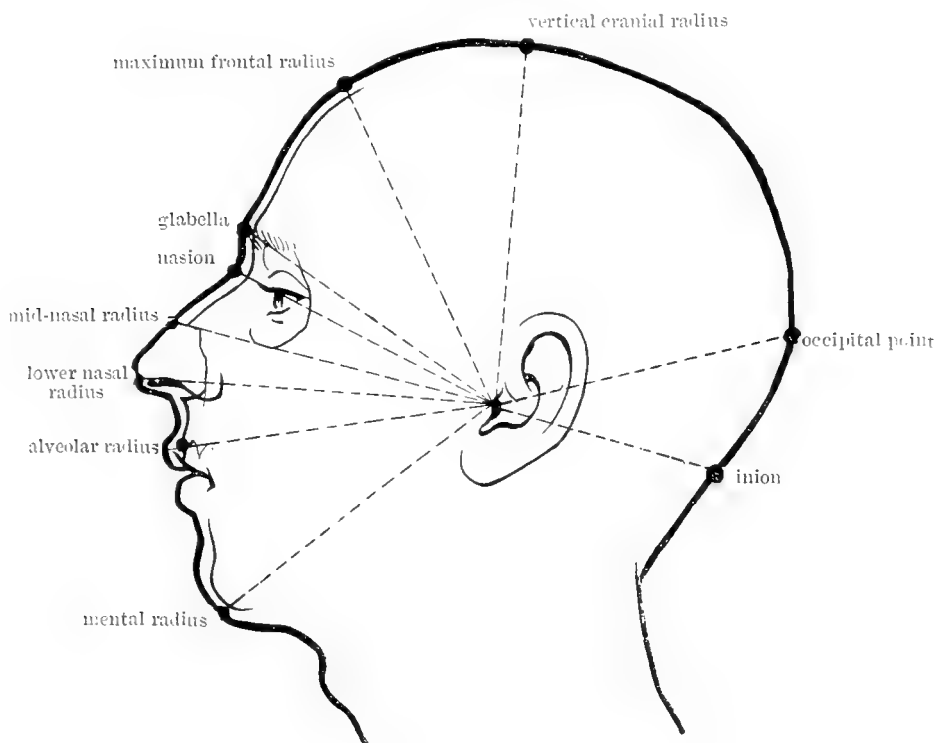
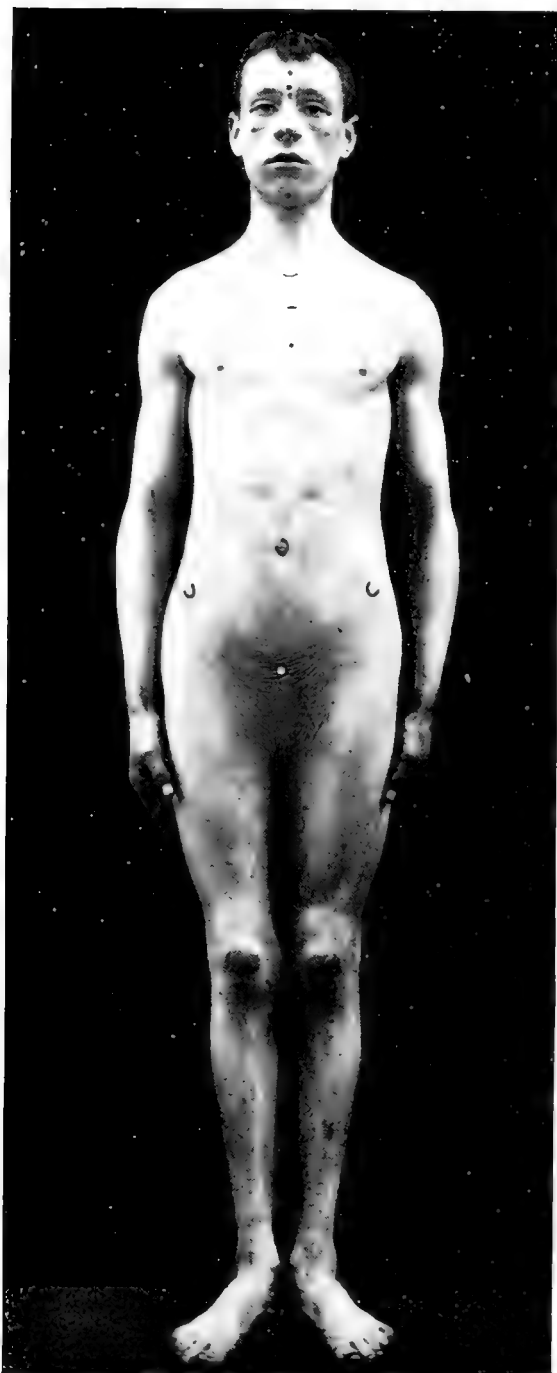


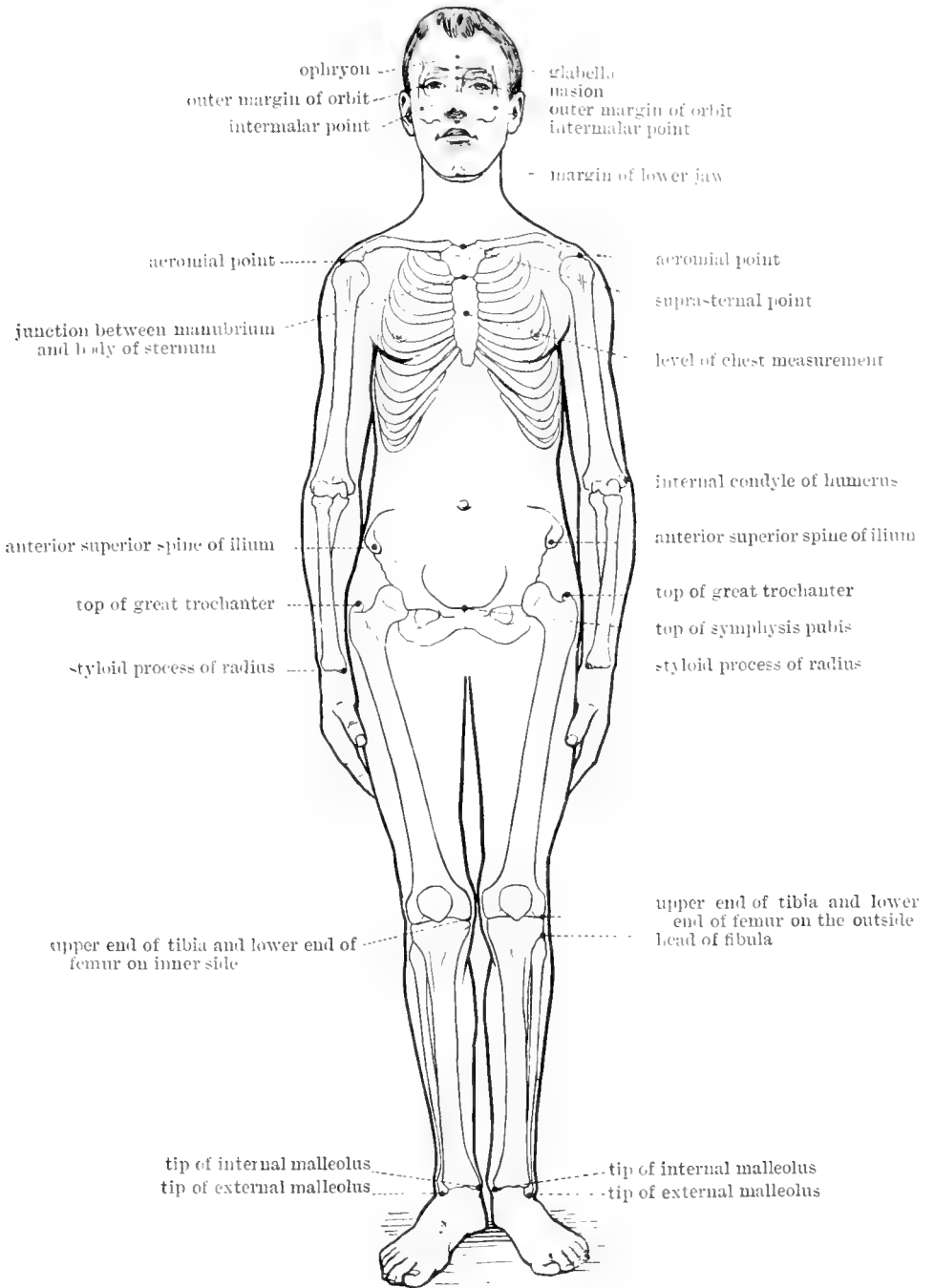
Diagram of Cranial and Facial Radii (Cunningham).

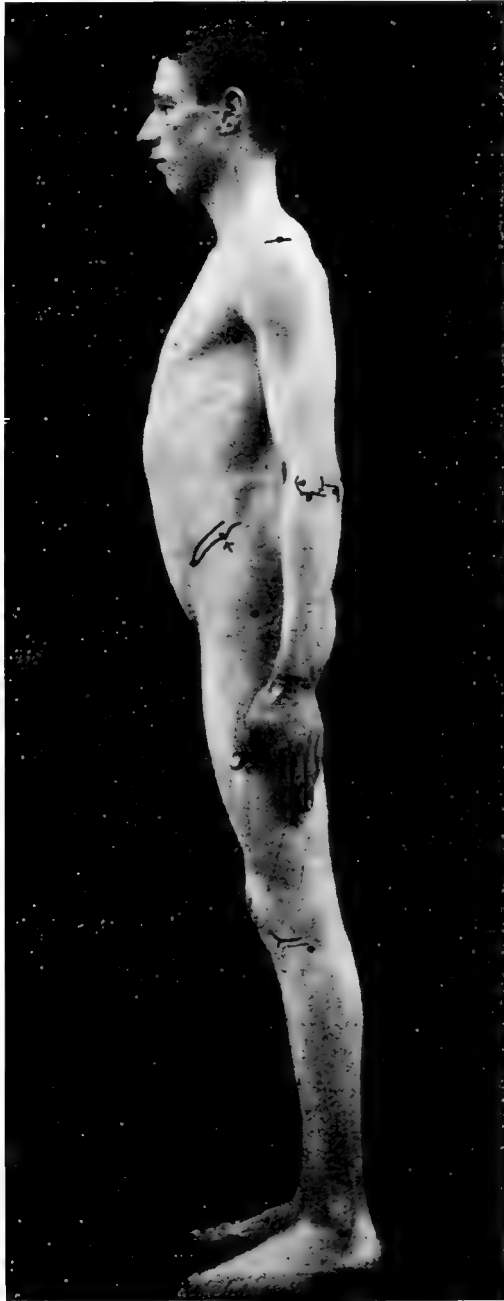
(The radii diverge from the centre of the ear-hole.)



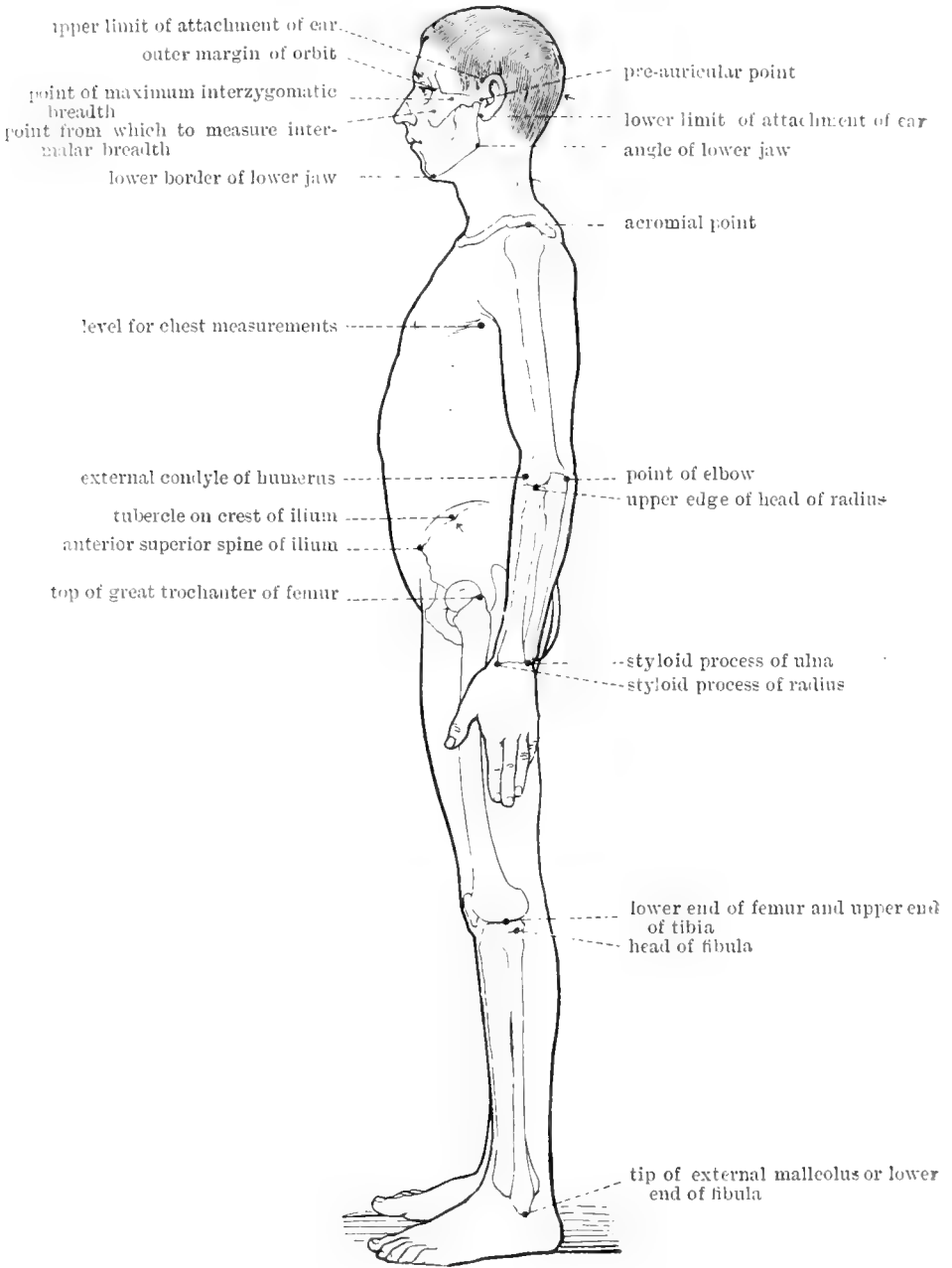


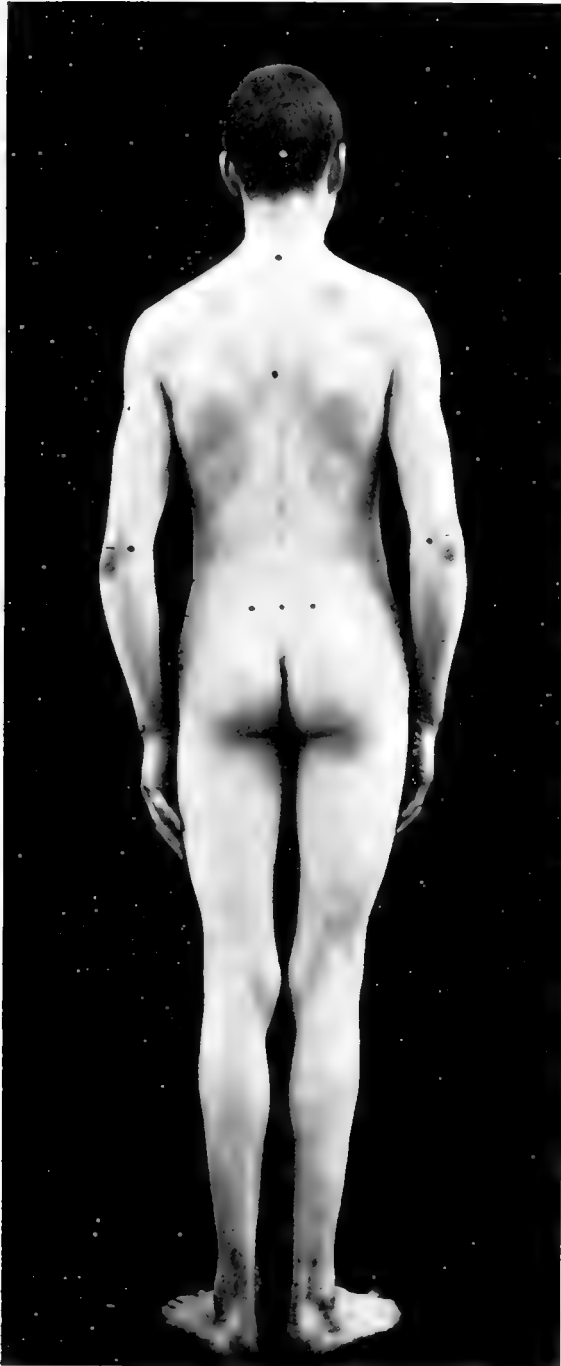
Front Aspect of Male Figure (Cunningham).





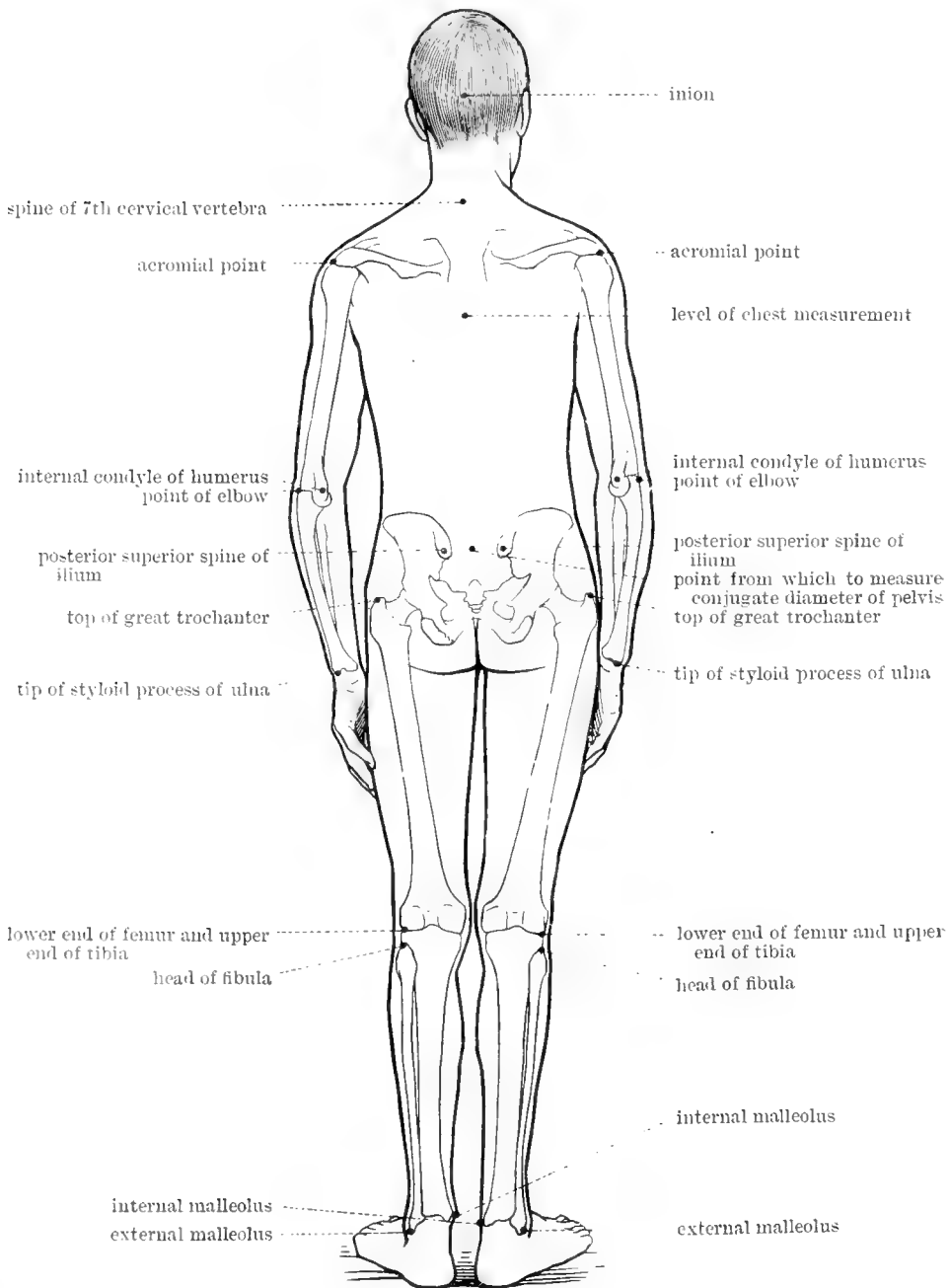
Left Lateral Aspect of Male Figure (Cunningham).





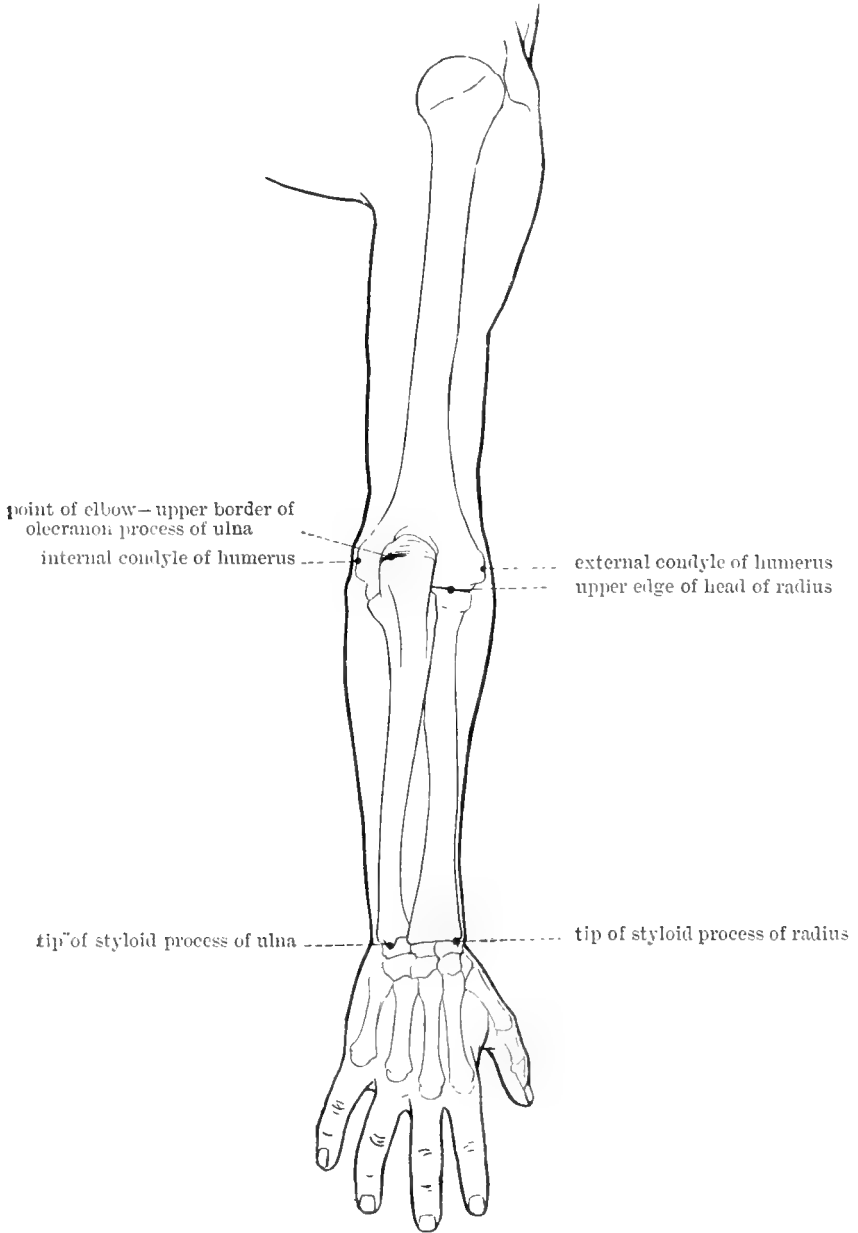
12
9
ALH

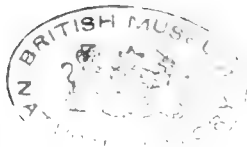
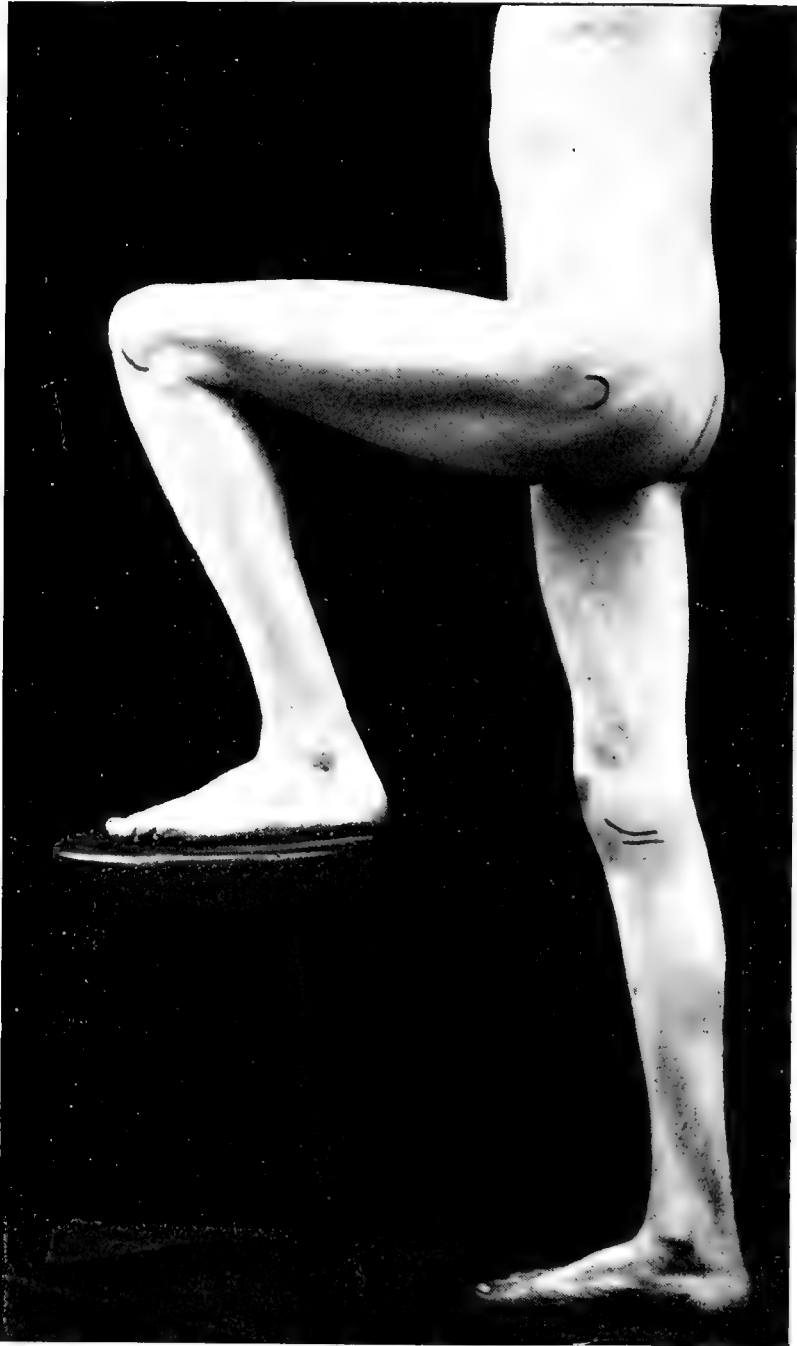
Back View of Male Figure (Cunningham).



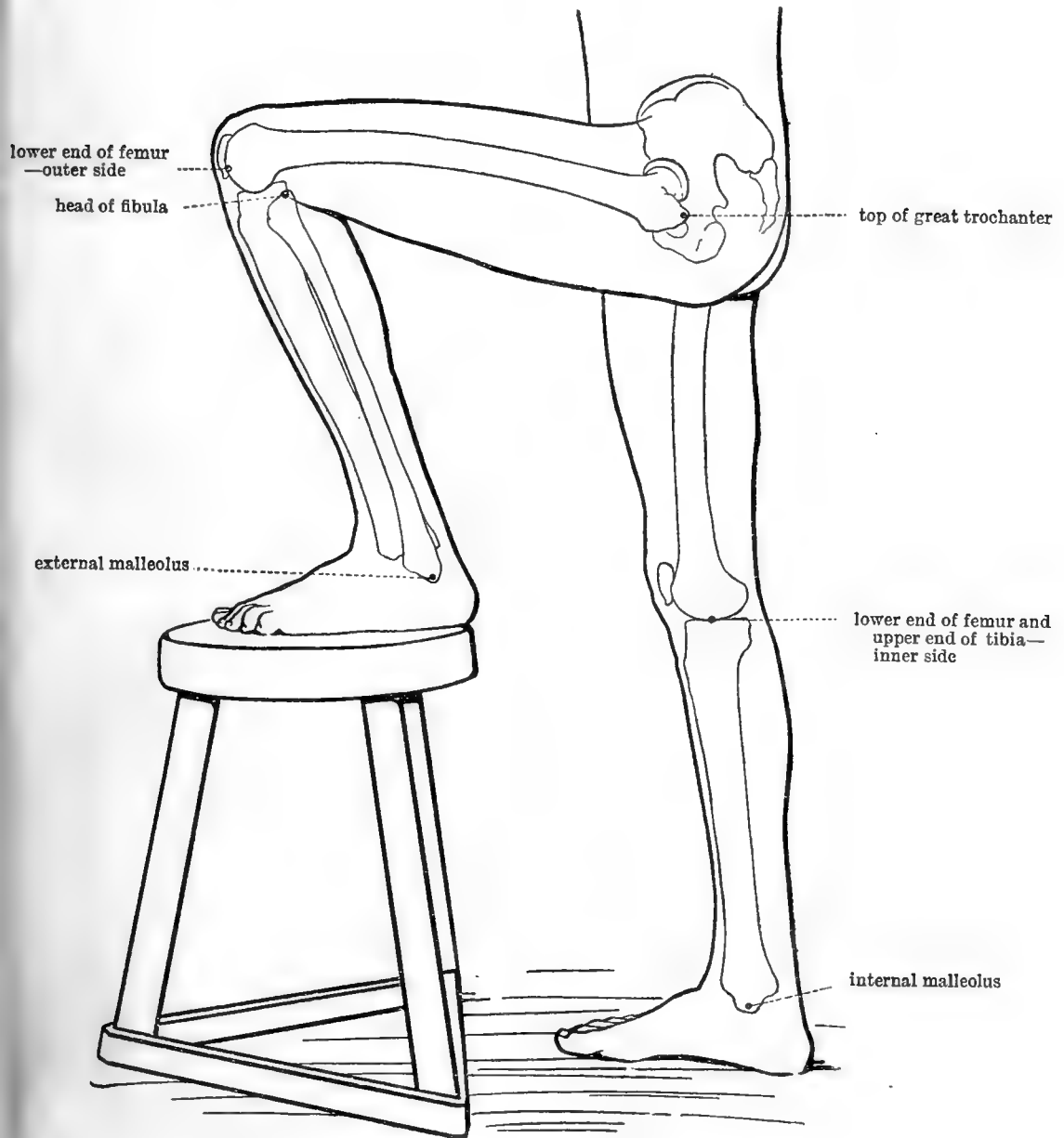


Posterior Aspect of the Fully Extended Right Arm (Cunningham).





Outer and Inner Aspects of the Lower Limbs (Cunningham).



The Age of Stone Circles.—Report of the Committee, consisting of Mr. C. H. READ (Chairman), Mr. H. BALFOUR (Secretary), Sir JOHN EVANS, Dr. J. G. GARSON, Dr. A. J. EVANS, Dr. R. MUNRO, Professor BOYD DAWKINS, and Mr. A. L. LEWIS, appointed to conduct Explorations with the object of ascertaining the Age of Stone Circles. (Drawn up by the Secretary.)

OWING to the late date at which excavations were conducted in 1905, the presentation of the Committee's report was unavoidably deferred to the present year.

The Committee, after having considered various possible sites for excavation, finally decided upon the examination of the stone circle known as the 'Stripple Stones,' situated upon the slopes of Hawkstor, near Blisland, Cornwall. This circle is by no means a fine one, but it is one of the few which are surrounded by a definite fosse, and it was considered probable that, as in the case of the circle at Arbor Low, which had previously been examined, the evidence derived from objects found under the silting of a fosse would be of a more convincing nature, as furnishing a clue to the period to which the monument belongs, than that derived from other portions of a stone circle. A preliminary inspection of the circle was made by Mr. Henry Balfour in company with Mr. H. St. George Gray, and the suitability of the site was reported upon to the Committee. Leave to conduct excavations was kindly given by the owner of the land, Sir William Onslow, Bart., to whom the Committee tender their hearty thanks. As in former years, Mr. H. St. G. Gray, of Taunton, was placed in charge of the excavations, under the general direction of the Committee. The Committee's sincere thanks are due to the Rev. E. Vernon Collins, Rector of Blisland, through whose kindly help in securing the co-operation of the tenant-farmer, Mr. W. Jane, and in advising as to the employment of local labourers, and in a variety of other ways, the preliminary arrangements were very greatly facilitated. The value of his assistance cannot be over-estimated, and his friendly hospitality and the interest which he throughout displayed in the work were very much appreciated.

The excavations were conducted by Mr. Gray with great care and attention to detail, under trying circumstances to some extent, owing to wet weather, which hampered the work considerably. The results, as far as 'finds' are concerned, were disappointing. With the exception of a few flints showing human workmanship, practically nothing was discovered, in spite of a large area of the circle and fosse having been very thoroughly explored. The scarcity of relics was, in fact, most striking, and would seem to point to the probability of the circle having been for occasional and not prolonged use, presumably for sporadic ceremonial purposes alone. The total absence of metal amongst the 'finds' is noteworthy, and it may perhaps be fairly assumed that the period to which the 'Stripple Stones' circle belongs is materially the same as that assigned, on better evidence, to the far finer circle at Arbor Low in Derbyshire, viz., not earlier than *late* Neolithic times, nor later than the *early* Bronze Age. It may at least be said that no evidence was forthcoming tending

to suggest that these two circles belong to different periods. In structure they present similar general features, although the external characteristics which are so splendidly defined at Arbor Low are considerably obscured at the 'Stripple Stones,' where the very slight fosse and vallum, though distinguishable in places, are very ill-defined and even untraceable in other parts.

An admirable survey of the 'Stripple Stones' was made by Mr. Gray, whose detailed report upon the circle and the excavations is appended; and, in addition, surface examinations were made of the Trippet Stones and Leaze Circles, plans of which were prepared.

The Committee ask to be reappointed and to be allowed to retain the unspent balance of the grant, with a view to its being used to cover the expenses of Mr. Gray and an assistant in making accurate survey plans of Fernacre and Stannon Circles, in order that the survey of the whole of this group of Cornish circles may be completed. It is not proposed to conduct further excavations—at present, at any rate.

Excavations at the Stripple Stones, E. Cornwall, 1905.

By H. ST. GEORGE GRAY.

I. The Position of the Circle.

The Stripple Stones—the largest stone circle of Devon and Cornwall, excepting the Fernacre Circle, which equals it—is situated in East Cornwall, in the ancient deanery of Trigg Minor, on the portion of Bodmin Moors known as Hawkstor Downs. From Bodmin the circle is $7\frac{1}{8}$ miles, as the crow flies, in a N.E. direction; $9\frac{1}{2}$ furlongs N. of Temple; 3 miles E.N.E. of Blisland Church (in which parish it is located); and $5\frac{3}{4}$ miles S.S.E. of Camelford. The most important ancient monuments in the vicinity are at the following distances from the Stripple Stones:—The Trippet Stones, W.S.W., 4,170 feet (over $\frac{3}{4}$ mile); the Leaze Circle, N.N.W., 7,230 feet (rather less than $1\frac{1}{2}$ mile); the Stannon Circle, N.N.W., 16,850 feet (about $3\frac{1}{4}$ miles); the Fernacre Circle, due N., 15,730 feet (3 miles); and King Arthur's Hall, N.N.W., about $1\frac{3}{4}$ mile. The nearest part of the disused Hawkstor china-clay works is $\frac{1}{2}$ mile distant to the S.W., between which and the circle is a small farmhouse. Hawkstor farmhouse is about $\frac{1}{4}$ mile to the N.E. Neither of these farms is marked on the 6-inch Ordnance sheets published in 1890.

There is a barrow to the E., containing a cist, in the adjoining cornfield, which, according to Mr. Lukis, is 232 feet from the stone in the middle of the circle.¹

The circle is on the S.E. slope of Hawkstor, about 90 feet lower than the summit, *i.e.*, about 915 feet above sea-level. Open downland surrounded it on all sides until recent years; but in or about 1885 a new 'take,' or enclosure, was made, the N.W. and N.E. walls of which were built across the E. and N.E. portions of the vallum of the Stripple Stones, which has entirely ruined these parts of the circle, fosse, and vallum.

The area on which the circle is placed, although on a gentle slope, is flatter than any of the ground in the immediate vicinity.

Rough Tor is due N. of the Stripple Stones, and Garrow Tor and the

¹ My own measurement gave 236 feet from the approximate centre of the barrow to the N.W. corner of the central stone of the circle.

Fernacre Circle fall in the same line precisely ; and a line connecting the Stripple Stones with the Leaze Circle and extended in a N.W. direction passes through the Stannon Circle.

The remains of hut-circles abound in the vicinity of the Stripple Stones. There are large groups to the E.S.E. and S.E. on Brockbarrow and Blacktor Downs, and there are many good examples on the downs near Blisland and on Kerrow Downs.¹ It seems to be highly probable that these were the dwelling-places of the people who constructed and used the neighbouring stone circles, but as yet we have no absolute proof that the same race erected the circles and the huts.

II. *Description of the Circle.*

The plan encloses an area 280 feet from due N. to S.² by 260 feet from E. to W., the ground covering 1.67 acre. The original plan was plotted to a scale of 192 to 1 ; in other words, 16 feet to an inch. The magnetic variation for January 1, 1905, at Temple was 17° 35' west of true north.³ The plan with its 6-inch contours shows a maximum fall of 10 feet from the highest ground in the N.W. corner to the lowest at the S.W. corner. The area encompassed by the stones is almost level at the centre and at the N., N.E., and E. ; the greatest fall of this plateau, viz., 2 $\frac{3}{4}$ feet, is from N.N.E. to S.S.W.

The Stripple Stones circle was selected for excavation by the Committee, being one of the few stone circles surrounded by a vallum and fosse, the latter within the former. The other circles of this type, all of which have better-defined valla and fossæ than the Stripple Stones, are : Avebury (Wilts), Arbor Low (Derbyshire), and Stennis (Orkney).

The vallum and fosse enclosing the Stripple Stones are very irregularly defined, and from external appearances at the present day it cannot be stated that any fosse exists except on the W., N.W., N., and N.E. At these points the surface of the silting in the middle of the ditch is 1.5 foot lower than the adjacent central area on which the monoliths rest. The highest part of the existing vallum is on the N.W., where it rises to 3 feet above the surface of the silting of the ditch and 1.5 foot above the central area. It is about the same height on the N.E. near the wall, but on the N. there is a considerable flattening of the bank, which appears to be a modern mutilation.⁴ 'Bays,' or recesses, in the outer margin of the fosse are seen by the contours to exist at the present time on the W.N.W. and a little W. of true N. These features are very unusual. Mr. Lukis stated that there were three 'semi-lunar projections in the vallum on the N.W., N.E., and E.'⁵ The two former still exist, but the eastern one has been destroyed with the rest of the earthworks on that side, owing to the formation of the modern enclosure, previously referred to.

Coming round to the W.S.W. side, there is a gap in the vallum for a

¹ I photographed one of the Kerrow hut-circles.

² My plans of the Trippet Stones and the Leaze Circle have margins due N. and S. and E. and W.

³ My thanks are due to the Director-General of the Ordnance Surveys, Southampton, for this information ; also to Capt. J. E. Acland and Mr. C. H. Samson for the loan of levelling-rod and prismatic compass.

⁴ Carts going from Hawkstor Farm to the main Bodmin and Launceston road (*viâ* the disused china-clay works) traverse the middle of the circle from N. to S.

⁵ *Prehistoric Stone Monuments of Cornwall*, p. 3 and pl. viii. 'Mag. N. Mer. taken to be 20° 30' W. of N.' (Lukis, 1879.)

distance of about 15 feet, and the ditch loses itself in what appears to be the ancient entrance or approach to the central area.

With regard to the southern half of the enclosure, a rampart exists, averaging 1·5 foot in height, very irregular and ill-defined; but from superficial appearances no ditch can be said to exist on the S.W. and S., although *slight* traces of one are observable around Stone XVII, and to the N.E. of it nearly as far as the S.E. wall. On the S. and S.S.W. the rampart is little more than 0·5 foot high, and a modern cart-track, 8 feet wide, on the S.S.E. entirely obliterates the bank.

The approximate diameter of the crest of the vallum is 224 feet, estimated from a *centre* $2\frac{3}{4}$ feet to the N.W. of the N.W. corner of the central monolith (No. I). The crest of the vallum deviates very slightly from the true circle, except on the N.N.E., where it bulges out a little. The ditch at the Stripple Stones is more irregular than at Arbor Low. Describing a circle from a point 5 feet S.S.W. of the N.W. corner of the central stone, we get an approximate diameter of 197 feet for the ditch.

The monoliths comprising the Stripple Stones were found to be arranged in relative positions approximating to a true circle, having a diameter of $146\frac{1}{2}$ feet, the *centre* occurring 2·5 feet to the W.N.W. of the N. point of the central prostrate stone. Mr. Lukis gave the diameter of the circle as $148\frac{1}{2}$ feet, but Mr. Lewis has already pointed out that 'it is doubtful from his own (Lukis's) plan whether it is not 2 feet less.' The Fernacre Circle is, according to the measurements of others, of precisely the same diameter as the Stripple Stones, viz., $146\frac{1}{2}$ feet. Whether this was the result of accident or intention on the part of the constructors we have no positive means of ascertaining.

Of the four stones still standing at the Stripple Stones, viz., Nos. IV, VII, X, and XIII, all fall in the line of the true circle except No. VII, which, like No. II in the case of the Leaze Circle, is placed a foot or two on the outside. The monument was undoubtedly intended to have a true circular form, but the modes of measuring adopted by the early constructors were probably of a primitive and inexact kind. Although the recumbent stones do not all now fall on the periphery of the circle, there is no reason to suppose that any of them, when in their original erect positions,¹ were misplaced even as much as standing-stone No. VII, viz., 2 feet. Taking the present position of the remaining stones into consideration, and the gap existing between Stones II and XVI, it may safely be stated that the circle originally consisted of twenty-eight standing-stones, placed at an average distance of $16\frac{1}{2}$ feet apart. Of stones in their relative positions in the true circle there are at the present time four standing, one (No. XVI) almost recumbent, eight recumbent, and one (No. V) which may not have been a stone of the circle, but merely a modern introduction when the wall was built. In Mr. Lukis's plan (1879) we get five standing stones and ten prostrate stones falling in the line of the circle, which shows that during the last three decades the Stripple Stones have altered much from pillage.

The standing and recumbent stones rest in depressions, but those of the former, as one would expect, are more pronounced than the latter. Needless to say, cattle and other domestic animals constantly use the standing-stones for rubbing against, the operation increasing the depth of these hollows, which in wet seasons are filled with water.

¹ Stones VIII, XVII, and XVIII are, of course, not under consideration in this respect.

The highest stone remaining standing, No. XIII, is 6·9 feet above the surrounding depression, and about 5·9 feet above its tussock. Standing-stone No. X is the next highest, being, on its N. face, 6·1 feet above its depression, and about 5·1 feet above its tussock. Both lean considerably, No. XIII towards the E., No. X towards the S. No. VII is the only stone fairly erect; it stands 5·9 feet above its depression, and 4·75 feet above its tussock. Standing-stone IV leans towards the S., its height being 4·8 feet above depression and about 3·8 feet above its tussock.

The largest remaining prostrate stones of the *circle* are Nos. III, IX, and XV, each being about 10 feet in length; No. IX is the broadest. The longest remaining prostrate stone of the whole group is the central monolith, the maximum length (E.N.E. edge) being 12·2 feet. The largest prostrate stone in the middle of Arbor Low is exactly 2 feet longer.

No isolated standing monoliths were noticed near the Stripple Stones.

III. *The Excavations, 1905.*

The excavations and surveying continued from June 22 to July 4 inclusive.¹ Much wet weather was experienced during the second week, and it was with great difficulty that the plan was finished. From five to seven men were employed.

Twenty-five distinct excavations or cuttings were made in various parts of the area included within the outer margin of the vallum, viz., eleven in connection with the position of the stones, ten for the purpose of tracing the fosse, two cuttings through the vallum, and two other cuttings in the interior space. In addition, the cist in the cornfield was re-excavated, but no relics were found. With regard to 'finds,' the results have been far more unsatisfactory than in the case of the Arbor Low excavations, and the only relics found at the Stripple Stones consist of three flint flakes, a burnt flint, portion of a radius (probably of ox), and several pieces of wood in the silting of the ditch on the north.

It is quite probable, as Mr. A. L. Lewis has suggested to me, that the few flint flakes found were brought from the banks of the Dozmare, Dozmary, or Dosmar, Pool, the largest piece of water in Cornwall, at a distance of 3 miles from the Stripple Stones in a direction a little S. of E. Mr. Lewis has several flint flakes from Dozmare, and there is a large quantity of them in Plymouth Museum; also in the British Museum. Nos. 1 and 4 (the latter in particular²) from the Stripple Stones bear a strong resemblance to those from Dozmare.

Excavations round the Stones.

Central Stone No. I.—A rectangular area, covering $53\frac{2}{3}$ square yards, was excavated round this stone, the sides of the cutting measuring 23 feet from N.W. to S.E. by 21 feet from N.E. to S.W. To an average depth of 0·7 foot from the surface brown peat, very tough and fibrous, was found to extend. This corresponds with the peat of Dartmoor, locally known as 'ven' or 'fen.' Below this a black peaty mould was dug through, thickness from 0·8 foot to 1·6 foot; in places it was mixed with large and small blocks of granite. Below this, at depths varying from

¹ Mr. Henry Balfour (Secretary) visited the excavations on June 28. Mr. C. H. Read (Chairman) made two attempts to go down from London, but was prevented.

² The colour of this specimen, like others of a long narrow form from Dozmare, is a milky-greyish-brown.

1·5 foot to 2·3 feet from the surface, a thin layer of bog iron-ore, or 'pan,' occurred, through which it was noticed roots did not penetrate. Immediately below this ferruginous deposit the subsoil was reached, consisting of a light-coloured compact sandy material derived from decomposed granite. The excavations were discontinued at this layer.

During these operations the following flints were discovered: At '1' on plan,¹ at a depth of 1 foot, a flint flake, or knife, with prominent bulb of percussion and conchoidal fractures; at '2' another flint flake with secondary chipping, and a well-defined bulb of percussion with an *écaillage* on it, depth 1·2 foot; and at '3' a small piece of calcined flint, depth 0·8 foot.

In four places in this excavation the hard layer of bog iron-ore was found to be deficient; digging was therefore continued to a greater depth, and four distinct holes were found as indicated on the plan, one on the S.W. of the stone, and three on the E. and N.E. sides. The first hole, 'W,' was of oval outline, 5·5 by 4 feet at the layer of iron-ore; the bottom was 3·5 feet below the surface of the turf. Holes 'X,' 'Y' and 'Z' were of irregular outline; 'X' measured 4·5 by 2·7 feet at the ferruginous layer; 'Y,' 3·1 by 2·1 feet; and 'Z,' 4·5 by 3 feet. All were filled with peaty mould and pieces of granite; no relics were discovered in them, and their purpose is uncertain.

At the S.S.E. end of this large monolith a hole full of water was discovered; the stone extended a few inches further in a S.S.E. direction than the margin of the hole. The hole was found to be about 5 feet long and 2·8 feet wide. We therefore obtained satisfactory proof that the stone stood erect at one time on what is now its S.S.E. end, at some 14 feet to the S.S.E. of the true centre of the circle; moreover, that the monolith in its fall in a N.N.W. direction had 'kicked out' to the extent of about 1·5 foot and covered the hole dug for its reception.

Towards the end of the time devoted to the excavations another plot of ground, 11 by 8·5 feet, was trenched over to the S.E. of the larger central area, but we were unrewarded. The bog iron-ore was found here as a fairly even layer at an average depth of 1·4 foot from the surface.

Prostrate Stone No. II.—As there was no depression at the N.W. end of this stone indicating the position in which it might have stood, and as there was a depression at the S.E., a hole was dug round this portion of the stone and partly under it. No hole was found in which the S.E. end of the stone could have stood, and as the other end falls in the line of the true circle there can be no doubt that it has fallen inwards in a S.E. direction. The layers of earth, &c., under the S.E. end of the stone were regular, and not mixed, as they would have been if a hole had been cut for the reception of the base of a monolith. The digging revealed the true thickness of the stone at the S.E. end to be 0·9 foot.

Prostrate Stone III.—This stone rested in a rather deep encircling depression; turf had grown considerably over the N. end; an excavation was made round the N. point and end of the stone, and the hole in which it originally stood was easily traced; the bottom in the undisturbed granitic sand was reached at a depth of 3·5 feet from the general level of the surrounding turf, and 2·4 feet from the surface of the monolith. From the excavation we ascertained that this slab averaged 0·75 foot in thickness. The point of the base in its fall appears to have kicked out

¹ Plans were submitted to the British Association together with this report, and it is hoped that they may be published later. The numbers here refer to one of the plans.

towards the N. to the extent of 1·7 foot. The iron-ore layer was seen in its usual position on the sides of the hole.

The most interesting result of this excavation was the finding of fairly large blocks of granite in such positions as to clearly indicate that they were packed into the hole as wedges to support the pointed base of the stone (*cf.* Stonehenge). This feature was not observed elsewhere during the excavations. No relics were found here, nor round Stones II or IV.

Standing Stone IV.—As this stone leans towards the S. to the extent of about 15° from the vertical, it was necessary to prop it up during the excavation with a stout pole. We reached the bottom of the stone, which had a flat base, at 1·1 foot below the depression, 2·1 feet below its surrounding tussock, and about 2·5 feet below the general turf level to the S.W. Peaty mould extended to a depth of 0·4 foot below the depression; the remainder, 0·7 foot, to the bottom, consisting of a sandy material derived from decomposed granite. There had been no attempt to pack the base with blocks of granite, only a few small pieces being found mixed with the soil, as in other parts of the circle. The total height of this monolith, including the portion sunk in the ground, proved to be 5·9 feet.

Between Stones VI and VII we made a small excavation 5 feet square, although the position was several feet outside the line of the circle. Before digging, a marked depression was observed, and it was thought possible that a stone might once have stood there. There was certainly a rough hole of artificial character, but nothing was proved by the excavation.

Standing Stone VII.—An oval area measuring 16 by 14 feet was trenched round this erect stone. The stability of the stone was not interfered with, as the hole in which it stood was not disturbed, nor the tussock encircling it. This excavation was made in the endeavour to find relics round the stone, but nothing was revealed.

Standing Stone X.—With the same object in view an oval area 17 by 15 feet was trenched round this stone and up to Stone IX, now prostrate. As in the case of Stone VII, the hole in which it stood was not interfered with, and the trenching was not carried to a greater depth than the layer of bog iron-ore. At '4' on plan, 5 feet S. of the stone and 0·9 foot beneath the surface, a long and narrow flint flake (length 65·5 mm.) was found. It has a pronounced dorsal ridge, and is of triangular cross-section; a small facet known as an *écaillage* exists on the bulb of percussion.

Prostrate Stone XI.—Excavations round this stone revealed no hole, penetrating the subsoil, in which it could have stood. This negative evidence was what we wanted, as it will be seen by reference to the plan that the stone rests 5 or 6 feet to the S. of the place in which we should expect to find it, *viz.*, in the line of the true circle. The digging showed that the stone was 0·8 foot in maximum thickness and that the S. end was quite flat. No relics were found here or near Stone XII.

Prostrate Stone XII.—Excavations were made round the N.N.E. of this stone to ascertain whether a pit existed on the line of the circle and whether the stone had fallen outwards. A distinct hole was discovered, it having been cut through the iron-ore floor reached at a depth of 1·1 foot from the depression in which the stone now rests. The pit was 2·5 feet deep below the field-level. The base was found to partly cover its hole. No packing of granite blocks for the support of the stone was observed.

Standing Stone XIII.—An area, 20 feet square, was trenched down to the iron-ore layer round this large standing-stone. The stone was not disturbed, and the tussock round it was left untouched. The only thing found here was portion of a radius, probably of ox, in the S.E. corner of the excavation, at a depth of 0·7 foot.

Prostrate Stone XIV.—An excavation was made at the S. end of this stone. It was found that a hole had been made only sufficiently large for the base of the stone; the hole penetrated the layer of bog iron-ore. The depth of the hole below the surface of the plateau (inside) was 3·1 feet; depth below the depression on the S.S.W. side, 1·1 foot. Here, again, we found nothing.

Hole on the N. W. of the Plateau.—Soon after our arrival a small hole or depression, maximum depth 1 foot from the level of the surrounding turf, attracted my attention, but a very hasty survey of the surroundings showed that it was considerably within the line of the true circle of stones, and that probably it did not mark the site from which a monolith had been removed. A rectangular area, 10 by 8 feet, was pegged off round this depression and was carefully excavated. The iron-ore floor was reached at 1·3 foot from the surface in all parts, except where the actual hole occurred. Above the iron and between it and the 0·5 foot of brown peat was the usual peaty mould. At the iron-ore floor the hole was found to be roughly circular and 3·5 feet in diameter, from which the sides gradually tapered to almost a point at the bottom; total depth from the surface of the plateau, 3·1 feet. No relics, or charcoal, or other substances were found; and the purpose of the little hole was not ascertained.

Excavations through the Vallum.

Two cuttings, each 10 feet wide, were made through the vallum, both near the entrance on the W.S.W. The lower margin of the westerly cutting was about 15 feet from the middle of the entrance, and the excavation was made in continuation of Cutting 2 through the fosse. The upper margin of the S.W. cutting was about 26 feet from the middle of the entrance, and the excavation was made in continuation of Cutting 5 through the supposed position of the fosse in this part of the earthwork.

Cutting 2.—The old surface line under the rampart could not be very distinctly traced, but its depth from the crest varied from 1·3 to 1·6 foot. The rampart was made up to some extent by blocks of granite mixed with black earth.

Cutting 5.—The old surface line was traced with some difficulty at a depth of 1·5 foot below the crest of the rampart. The upper 6 inches, as elsewhere, consisted of peaty turf and black mould, below which the earth, mixed with some granite stones, became of a more ferruginous nature.

Excavations into the Northern Fosse, and Cuttings made in the endeavour of ascertaining whether a Fosse ever existed in the Southern portion of the Circle.

Twelve cuttings were made of various dimensions, three being on the N. and W. in places where the original existence of a fosse within the vallum was clearly observable, and nine smaller cuttings made from the W.S.W. to the E.N.E. in positions within the vallum in which a cut ditch would be found if any had existed from the days of the construction

of the circle. Much time was spent in this department of the excavations, and it is with regret that I have to report that no objects of antiquity (except a few pieces of wood) were found in any of the cuttings connected with the fosse. Firstly, we will deal with Cuttings 1 to 3, from the N. to the W.S.W., where the existence of an ancient ditch was a certainty.

Cutting 1.—By far the largest excavation made at the Stripple Stones was 88½ feet of fosse on the N. and N.W. The maximum height of the vallum in this part above the silting of the ditch is 3 feet, while the nearest part of the central area occupied by the monoliths is 1·5 foot higher than the middle of the silting. This part of the ditch, we are told, is generally full of water during wet weather, and it was not entirely dry during the time of the excavations. We commenced digging at the W. end of the area selected, where the margin of the ditch was found to be about 9·5 feet wide, and the depth of the silting 2·45 feet in the middle, of which 1·8 foot consisted of turf, peat and mould. Below this the silting was composed of rather fine granitic sand, which had, doubtless, been washed down from the sides of the ditch when it had been open to the bottom. For 20 feet or so no great change was found in the character or depth of the fosse; a section was taken at C.D. which gave a width of 9 feet at the top of the ditch and 1·1 foot at the bottom, with a depth of 2·2 feet. In no part of the ditch were the sides steeper than here. As the work continued, it was found that the average width at the top was 9·5 feet for three-quarters of the length of the cutting; but at the E. end it gradually expanded to a maximum width of 16 feet.¹ The bottom of the fosse in the E. half of the cutting was not clearly defined; indeed, in most parts the bottom presented a concave surface in a continuous curve with the sides of the fosse. As will be seen by the photographs of this excavation,² the slope of the sides of the fosse was very slight, and it became evident that the constructors paid little, if any, attention to symmetry or design. A portion of the N. margin of this fosse is marked on the plan by a dotted line at the point where one of the 'bays' or recesses occurs; but I am not sure whether our excavation here should not have been continued further N. to find the true margin of the fosse, which possibly followed the 'bay' to a greater extent than my plan indicates. On the extreme east of the cutting the cut bottom of the fosse began to show itself again. Here the fosse reached its greatest depth, viz., 3·4 feet below the surface of the silting. The filling at this end of the cutting consisted of peaty-turf 0·5 foot, followed by black earth mixed with roots and a little sand for a depth of 2 feet; at the bottom, granitic sand washed down from the sides, or profile, of the fosse.

In the silting of the fosse of Cutting 1, and in the N.E. half, nearly a dozen pieces (mostly small) of dark wood were uncovered in a saturated condition. They were found just above the granitic sand silting, in the black earth, at an average depth of 2·3 feet from the surface. Three typical pieces were sent to Mr. Clement Reid, F.R.S., for microscopical examination. They prove to be oak; some bear traces of rough cutting, but it is difficult, if not impossible, to say definitely whether any of the cuts or hacks were made before the wood became deposited in the silting.

¹ Owing to the nature of the material in which the fosse had been cut, it was found very difficult to determine even the approximate width of the original fosse at the eastern end of this cutting.

² A number of photographs were taken, some of which it is hoped will be published later.

The greater part of the sides of the lower portions of the re-excavated fosse was thinly covered with iron-pan. It has probably all become deposited since the time the fosse was allowed to silt up—from natural causes. As before stated, the lower portion of the silting was caused by denudation of the sides of the fosse. The oxide of iron contained in this granitic sand, or decomposed granite, was taken up by water constantly filtering through the silting, and, being arrested by an almost impervious stratum of the compact decomposed granite, forming the walls and bottom of the fosse, became deposited, but very slowly, as a thin layer of the hard ferruginous substance known as iron-pan. Mr. Clement Reid kindly examined a sample of the granitic sand derived from this fosse.

Cutting 2.—This cutting through the fosse was made a little to the N. of the entrance on the W.S.W. It was 10 feet wide, and in continuation of it a cutting through the vallum (already described) was made. A slight ditch was found, the maximum depth from the surface of the silting being 1·4 foot in the centre. The bottom was cut in a rounded form into the decomposed granite sub-soil. The iron-pan deposit was reached on the sides of the ditch at a depth of 0·8 foot from the surface, so that the ditch was cut into the sub-soil only to the extent of 0·6 foot. At the iron-ore layer the ditch measured from $2\frac{3}{4}$ to 3 feet in width; at the surface it averaged 4·8 feet.

Cutting 3.—The excavation of the fosse was continued from Cutting 2 in the direction of the entrance to the circle. At the end of the vallum the ditch was found to make a slight bend outwards in a S.W. direction; and instead of terminating abruptly in a rounded end, as most ditches do in such positions, it became shallower as we proceeded, and the sides much less steep; at 14 feet from Cutting 2 it died away entirely, and could be traced no further. There were slight indications on the surface of a little muddy gutter continuing from this point in a S.W. direction; and no doubt in winter-time, when the deeper ditch on the N. becomes full of water, it drains from this site in the direction I have suggested.

From the entrance on the W. to the modern stone wall on the E. no trace of a fosse within the small rampart was observable on the surface; and in order to ascertain whether a ditch originally existed on this side of the circle, seven distinct cuttings, mostly of small size, were made in the hope of settling the point. No hollow, or depression, was observable immediately within the margin of the vallum, except near Stone XVII, for a distance of about 50 feet, as shown by the contours.

Cutting 4.—This excavation was 25 feet in length, and it differed from Cuttings 5 to 10 inasmuch as the more or less even and regular layer of bog iron-ore had been penetrated¹ by the constructors of the circle. Although the ditch in Cutting 3 terminated at the entrance in such a peculiar manner, the end of the little ditch on the other side of the entrance exhibited a normal outline, having a rounded end such as we expected to find on the N. side of the entrance. By the excavation of Cuttings 3 and 4 we have proved that the width of the entrance between these two ditches was only 9 feet. The N. end of Cutting 4 was in line with the rounded end of the vallum at the S. of the entrance. The existence of a small fosse was traced in the N.W. half of this cutting, but it was very indefinite at the S.S.E. end. The depth of the little fosse was 1·7 foot from the surface of the filling. The average width of the

¹ The iron-ore had been penetrated here and two or three inches of the material beneath it.

N.W. half was 2·5 feet at the bottom of the fosse, 4 feet at the iron-ore layer, and 6 feet at the surface. The silting consisted of 0·5 foot of peaty turf, 0·7 foot of black mould, and 0·5 foot of dark brown mould at the bottom.

Towards the S.S.E. of this cutting the ditch was shallow, and although hollows (sometimes 0·25 foot deep) were observed in places in the iron-ore layer, it had not been penetrated here as at the N.W. end of the cutting.

Cuttings 5 to 10 were made for the same purpose of endeavouring to trace a fosse. The iron-ore floor was reached at an average depth of 1·7 foot, but it had not been penetrated. In these cuttings the iron-ore was sometimes fully $\frac{1}{2}$ inch in thickness, and exhibited bulbous projections or knobs on the upper surface; as would be expected, roots of grass, &c., had not penetrated it, but formed a tangled compressed mass on its surface.

Cuttings 11 and 12.—In the cornfield on the E. the plough had almost obliterated all traces of the vallum. A slight dip in what remains of the vallum was noticed, and thinking it possible that an entrance existed on this side of the circle approximately in line with the central monolith and the western entrance, I caused these two cuttings to be made, $5\frac{1}{2}$ by 4 feet and $13\frac{1}{2}$ by 4 feet respectively, one on each side of the depression above referred to. The result was disappointing; no relics were discovered, and no trace of a ditch was found, the iron-ore being reached at an average depth of 1·5 foot below the surface.

IV. *Summary and Conclusions.*

The Stones.—From eleven cuttings and excavations made in the immediate vicinity of four standing and seven recumbent stones and from other evidence we are able to establish the following conclusions:—

1. That all the monoliths (originally probably 28 in number) formed a circle $146\frac{1}{2}$ feet in diameter and stood upright, about $16\frac{1}{2}$ feet apart.

2. That two recumbent stones have disappeared since 1879, when Messrs. Lukis and Borlase made their plan.

3. That Stone XVI, now almost prostrate, probably leaned to no very great extent in 1879, when Lukis and Borlase classified it as a standing stone.

4. That Stone VII is a little outside the line of the true circle, and that Stone XI has probably been moved a few feet southward since its fall.

5. That the central Stone No. I originally stood eccentrically on what is now its S.S.E. end.

6. That it is uncertain what were the original positions of Stones VIII, XVII, and XVIII, and whether Stone V belongs to the circle.

7. That the recumbent Stones Nos. III, XII, and XIV, and the standing Stone No. IV stood in holes cut for their reception, the average depth of the holes being 2·9 feet from the present surface.

8. That evidence was obtained that one Stone (No. III), with a pointed base, was partly supported by a packing of rough blocks of granite.

It is surprising that even four stones remain standing (No. VII still being vertical), considering the nature of the surface deposits and the subsoil.

The Vallum and Fosse.—The crest of the vallum, which is 224 feet in diameter, was probably intended to be concentric with the true line

of the stone circle ; it was found, however, to deviate to an inconsiderable extent. As previously stated, no relics were found in the cuttings made through the vallum ; and in this department of the excavations, as at Arbor Low,¹ no interesting deductions could be made.

The fosse from the N.E. to the W. was clearly defined on the surface before the excavations were undertaken, but from the W.S.W. entrance to the stone wall on the E.S.E. there was absolutely nothing superficial to suggest that a fosse ever existed. The excavation revealed a broad but irregular ditch on the N. and N.W. which averaged 2·9 feet in depth from the surface of the silting and 4·2 feet below the nearest part of the central plateau. At Cutting 2 a fosse was found in much diminished proportions, and at the entrance it did not penetrate the sub-soil, but terminated in the manner shown on the plan. A slight ditch was found to begin in line with the end of the rampart on the S. side of the entrance, but it could not be traced for many yards to the S.E. ; and in the next cutting, No. 4, and in the trial cuttings to the S.E. and E. the bog iron-ore was found as a solid floor.

Whatever the original purposes for such ditches and ramparts were, my opinion with regard to the N. fosse of the Stripple Stones is that it was intended to serve a practical and very necessary purpose as a means of drainage. The position is a very wet one, with moisture constantly flowing. The peaty ground and surface soil in this vicinity do not require a large amount of rain to render it very boggy ; and owing to the presence of bog iron-ore at a slight depth moisture remains near the surface for a considerable time. It would be very necessary to keep the central plateau tolerably dry, and such a ditch as that on the N., with its outlet at the entrance to the circle, would drain off most of the water derived from the higher ground, which would otherwise swamp the circle to a very uncomfortable extent in wet weather. If this were the purpose of the N. fosse we should not look for a ditch of similar dimensions in the S. half of the circle. Regarded from this point of view, we get an explanation why no ditch penetrated the sub-soil in the S. half of the circle ; and if a fosse existed there at all, it was very shallow, with perhaps the iron-ore layer as its bottom.

I offer these remarks merely as a suggestion, in the endeavour to explain the difficulties presented by the irregularity and character of the fosse.

Relics and Date.—The few relics discovered at the Stripple Stones give us absolutely no certain evidence of date ; and even if any of them presented characteristics of a definite period, the position in which they were found would render them comparatively useless as proof of date. The existence of flint flakes to the exclusion of metals does not necessarily establish an early date for the Stripple Stones, even if they had been found on the 'old surface line' under the vallum, or deep in the fosse ; and yet, considering the amount of digging done (25 cuttings, large and small), the total absence of bronze should have some significance. The evidence of date resulting from the excavations at the Arbor Low stone circle and at Stonehenge was strong enough to satisfy the most precise antiquary, but we have no direct evidence in the present case. It is only from negative evidence that we are in any way justified in suggesting a late Neolithic or early Bronze Age for the Stripple Stones. If we were

¹ *Archæologia*, vol. lviii., pt. ii., pp. 477, 478.

positive that these flint flakes were struck on the banks of Dozmare Pool, where similar flakes are found in association with flint arrow-heads, then we could date the flakes found at this circle with some degree of accuracy. We must bear in mind that none of the flakes were found nearer the present surface than 0·8 foot, and it is highly probable that this dimension represents the approximate thickness of the peat which has accumulated since the disuse of the circle. Therefore I think we are safe in regarding the three flakes and the calcined flint as having been dropped round about Stones I and X during an early prehistoric state of culture of uncertain age.

Seulture was evidently not the object of the circle, or we should probably have found human remains in the central excavation.

APPENDIX.

In addition to the work at the Stripple Stones, I made scale-drawings and copious notes of two of the four neighbouring stone circles, viz., the Trippet Stones and the Leaze Circle. It is hoped that these and the plan of the Stripple Stones will be figured in 'Archæologia' later on.

Trippet Stones.—This circle is situated in the parish of Blisland, on the Manor Downs division of the Bodmin Moors, 4,170 feet in a bee-line W.S.W. of the centre of the Stripple Stones. From Bodmin the circle is $6\frac{2}{3}$ miles in a N.E. direction; and from Port Isaac Bay it is barely 8 miles. It is about 799 feet above mean sea-level, and the moor in this part is almost level. The stones are arranged in the form of a true circle, and consist of eight standing and four prostrate monoliths. The N.E. portion is the most complete part remaining, and I estimate that twenty-six stones forming the circle originally stood at an average distance of $12\frac{3}{4}$ feet apart. The diameter of the circle is 108 feet. The stones vary in width from $1\frac{1}{2}$ to $3\frac{1}{2}$ feet, and in thickness from $1\frac{1}{3}$ to 2 feet. The three highest stones average 5 feet in height above the depressions worn round them; whilst the average height is 4·4 feet.

The Leaze Circle.—It is so named from the farm on which it is situated, and is in the parish of St. Breward. There are only four cottages within a mile of it. The De Lank River, which divides the parishes of Blisland and St. Breward, is less than $\frac{1}{4}$ mile to the E. and S.E. The circle is rather less than $1\frac{1}{3}$ mile to the N.N.W. of the Stripple Stones, and rather more than $1\frac{1}{2}$ mile to the N.N.E. of the Trippet Stones. It is about 815 feet above sea-level, but it is not visible from the four neighbouring circles. The circle has been mutilated to a large extent by the modern bank which divides it into two portions. The Leaze Circle consists of ten standing and five prostrate monoliths; the N.E. part is the most complete portion remaining, and it is estimated that twenty-two stones, forming a true circle having a diameter of 81 feet, originally stood at an approximate distance of 12 feet apart. The average height of the standing-stones above their encircling depressions is 3·3 feet. In width they vary considerably, viz., from 1·3 to 2·75 feet, and in thickness from 0·8 to 1·7 foot.

I hope to have the opportunity of making accurate plans (to the same scale) of the two neighbouring circles, viz., Fernacre and Stannon, in the near future; but time did not permit of my doing more than was accomplished on the Bodmin Moors in 1905.

Anthropological Photographs.—Report of the Committee consisting of Mr. C. H. READ (Chairman), Mr. H. S. KINGSFORD (Secretary), Dr. J. G. GARSON, Mr. H. LING ROTH, Mr. H. BALFOUR, Dr. A. C. HADDON, Mr. E. S. HARTLAND, Mr. E. HEAWOOD, Professor FLINDERS PETRIE, Mr. E. N. FALLAIZE, and Mr. J. L. MYRES, appointed for the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest. (Drawn up by the Secretary.)

THE Committee issue with this report a first list of photographs registered with them. All these photographs are of great anthropological interest, and it would be invidious to single out any series for particular mention. The Committee wish to express the hope that now that a fair start has been made with the register, all persons who have taken photographs of anthropological interest will send copies of them to the Committee for registration, so that the collection may be as representative and useful as possible. The Committee feel convinced that such a collection and register of photographs cannot fail to be of great service to students of anthropology.

In cataloguing the photographs the Committee have adopted a geographical classification, under continents, with subdivisions into countries, provinces, &c. The system of numbering the photographs is as follows: Each person or institution who may be expected to contribute largely to the collection is given a series of a thousand numbers, with which to number his photographs consecutively, and on his first series becoming exhausted another thousand is allocated to him. The first nine thousand numbers have been allocated as follows:—

- | | |
|------------|--|
| 1-2000. | The Anthropological Institute, 3 Hanover Square, W. |
| 2001-3000. | Mr. J. L. Myres, Christ Church, Oxford. |
| 3001-4000. | Dr. D. Randall-MacIver, Wolverton House, Clifton, and the late Mr. Anthony Wilkin. |
| 4001-5000. | Mr. T. V. Hodgson, 54 Kingsley Road, Plymouth. |
| 5001-6000. | Dr. C. S. Myers, Melrose, Grange Road, Cambridge. |
| 6001-7000. | Mr. J. L. Myres, Christ Church, Oxford. |
| 7001-8000. | Mr. Edgar Thurston, Government Museum, Madras. |
| 8001-9000. | Will be used for small series or single photographs, registered by persons who are not expected to contribute largely to the collection. |

The conditions under which photographs are accepted by the Committee for registration are as follows:—

- i. That a copy of the photograph should be supplied by the owner of the negative; and
- ii. That the owner should allow the Committee to have prints made for anyone recommended by them, at cost price, for purposes of study, but not of publication.

It is understood that the copyright of all photographs registered remains the property of the owner.

All photographs presented to the Committee should state :—

- i. The subject of the photograph, and the place where the original is (or was) to be found.
- ii. The name and address of the owner of the negative.
- iii. The whereabouts of the negative itself, *i.e.*, whether it is retained by the owner or deposited with a professional photographer or with the Committee, who have made arrangements for storage.
- iv. The terms on which prints, enlargements, and lantern slides will be supplied, when ordered through the Committee.

All photographs should, if possible, be printed by platinotype or similar permanent process, and should be sent in unmounted, as the Committee have made arrangements for having photographs mounted uniformly. There is no restriction as to size, but it is advisable that prints should not be larger than whole-plate.

All communications should be addressed to the Secretary to the Committee, Mr. H. S. Kingsford, Anthropological Institute, 3 Hanover Square, W., from whom forms for registration may be obtained.

Of the original grant of 10*l.*, 6*l.* 10*s.* has been expended in mounting and clerical work, leaving a balance of 3*l.* 10*s.* The Committee ask to be reappointed with the balance in hand, and with an additional grant of 10*l.*

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ENGLAND.

Photographed by Mr. T. V. HODGSON, 54 Kingsley Road, Plymouth.

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 Christ Church, Oxford.*

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ITALY.—*Photographed by Mr. J. L. MYRES, Christ Church, Oxford.*

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MALTA AND GOZO.—*Photographed by Mr. J. L. MYRES,
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AFRICA.

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The Roman numerals refer to the plates in Dr. Randall-MacIver and Mr. Wilkin's 'Libyan Notes.'

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ALGERIA.—*Photographed by the late Mr. ANTHONY WILKIN.*

The references are to Mr. Wilkin's 'Among the Berbers of Algeria.'

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EGYPT.—*Photographs taken by Dr. D. RANDALL-MACIVER, Wolverton House, Clifton.*

Illustrating the manufacture of Pottery in Upper Egypt. Published in *Journ. Anthropol. Inst.*, vol. xxxv.

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- 3653. The open-air furnace, showing firing of pottery, Asswan.
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The Roman numerals refer to the Plates in Dr. Randall-MacIver's 'Mediæval Rhodesia.'

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TUNIS.—*Photographed by Mr. J. L. MYRES, Christ Church,
Oxford.*

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Takruna.

2318. * General view from E.
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- 3516, 3536. Native hut in the forest.
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AUSTRALIA.

Photographed by Mr. F. R. SCOTT, Alice Springs. Re-photographed by the ELITE PORTRAIT COMPANY, 267 High Holborn, W.C.

8001. Kaitish male, æt. c. 45.

Photographed by Mr. T. V. HODGSON, 54 Kingsley Road, Plymouth.

- 4036, 4037. Murchison shield.

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OCEANIA.

Photographed by Mr. T. V. HODGSON, 54 Kingsley Road, Plymouth.

<i>Easter Islands.</i>	<i>New Zealand.</i>
4012. Ethnographical objects; gorgets, &c.	4006-4011. Ethnographical objects.
<i>Fiji.</i>	<i>Samoa.</i>
4017, 4018. Clubs.	4017, 4018. Clubs.
<i>Hervey Islands.</i>	<i>Solomon Islands.</i>
4001-4004. Paddles.	4013. Paddles.
4005. Ceremonial adzes.	4014-4016. Arrows.
<i>New Guinea.</i>	<i>Tonga.</i>
4019-4035. Ethnographical objects.	4017, 4018. Clubs.

Excavations on Roman Sites in Britain.—Report of the Committee, consisting of Professor W. BOYD DAWKINS (Chairman), Mr. J. L. MYRES (Secretary), Sir EDWARD BRABROOK, Professor W. RIDGEWAY, and Dr. T. ASHBY, appointed to co-operate with Local Committees in Excavations on Roman Sites in Britain.

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THE Committee has made itself acquainted, as in former years, with the course of the excavations which have been in progress on Roman sites in Britain during the past year, and has been favoured in certain cases with summary reports of the work done, an abstract of which is given in Appendices A, B, and C.

After full discussion of the circumstances thus brought to its notice, the Committee has decided to offer grants in aid of special researches on certain sites as follows :—

A. *At Caerwent, as in 1904 and 1905, for the following special objects :—*

(a) To examine the contents of wells found in the course of excavation, with special reference to the stratification of their contents, and to the identification of the remains of animals and plants which may be found therein.

(b) To determine the age and construction of the mound and ditch by cutting a complete section, or otherwise.

B. *At Melandra Castle, for special investigation of non-Roman and pre-Roman remains.*

C. *At Newstead, near Melrose, for special investigation of the contents of wells, in the same manner as at Caerwent.*

In the case of Silchester, to which the Committee made a small grant in 1904, no formal report has been received; but the contents of wells found in the course of the excavation have been examined as before. The report from Silchester, which is appended, merely records the general progress of the excavation, in continuation of the series of summaries communicated to the British Association in years in which grants of money have been made.

APPENDIX A.

Excavations at Caerwent, 1904-5. By T. ASHBY, jun., D.Litt., F.S.A.

(a) *Report upon the Investigation of the Mound.*—Upon the south, west, and north sides of the city traces have been found, within the city wall, of an earlier defence, in the form of a mound of very hard red clay—the local clay, but more compact and binding than this clay in its natural state: it can be recognised by its hardness when excavated, though there is but little difference in colour, and, further, by the existence on its surface of small pieces of charred twigs, which occur in less amount all through it. Just below it, too, there is also a layer of charred stuff—as if the brushwood on the site had first been set on fire, and as if that which grew on the top of the mound had also been burnt once or more.

After the necessary profile measurements had been taken, the mound was cut into in several places. The first section to be described was that to the S. of Room of 'House XII.' The material was here, as elsewhere, very hard red clay, with pebbles in it; 13 feet below grass level, at 10 feet from the wall of the courtyard (which interrupts its backward slope), a pocket of charred stuff and burnt bones was found, with some pottery, including figured *terra sigillata*, and the bottom of one *terra sigillata* vase, with inscription, OF. APRO (*C.I.L.* vii. 1336. 78). Under the mound itself one small piece of bronze, one bit of *terra sigillata*, one bit of pottery with rough black paste, and some grey pottery were found.

Another partial section was made a little further W., to the S. of Room 15 of 'House XII.' Here the crest of the mound was found to have been 5 feet only below ground. The hard clay layer was only 4 feet 7 inches thick at the crest and 3 feet on each side; it consisted mostly of dark clay, with a lighter layer between. Under it were found several bones and a flake of flint, also a bone pin and several pieces of pottery. The earth below it is gravelly, with chips of limestone in it. Below this, again, comes natural hard red clay. Immediately to the W. of the S. gate the mound was found to slope away in all directions, showing clearly that there was a break in it to let the road out. A good photograph of this portion was obtained. To the E. of the S. gate it was not found at first,¹ but eventually a limekiln was found cutting into the mound, which was perhaps used by the builders of the wall.

A similar section on the W. side of the city, W. of 'House VII.,' a little way S. of the W. gate, is published in the Caerwent Excavation Committee's Report for 1901.² Here there was a road at the bottom of the backward slope of the mound, on the further edge of which was the W. wall of the house. When the wall was constructed the house was extended over part of the road and the level slightly raised, inasmuch as the space between the mound and the city wall was naturally filled up.

On the W. side of the city the mound has been traced, and its profile ascertained a little way E. of the N. gate.³ It is intended to make investigations at other points further E.

¹ The excavations here were, owing to the presence of a walnut-tree (since removed), carried on under difficulties. A section is given in *Caerw. Comm. Report* for 1904 (*Archæologia*, vol. lix., pl. lxvi.).

² *Archæologia*, vol. lviii., pl. ix.

³ See *Caerw. Comm. Report* for 1901-3 (*Archæologia*, vol. lix.), 1906.

Two sections have so far been taken of the city ditch, one just outside the N. gate, the other some way further E.;¹ but it has not yet been ascertained whether the ditch originally belonged to the mound, the wall having thus been constructed on a shelf cut in the mound, and using the same ditch. This can probably be found out at the point indicated to the N. of the amphitheatre, and it would be in this work, in taking another section of the city ditch and in working any wells that may come to light, that the balance of the British Association's grant for last year and the grant for the present year would be expended.

(b) *Sundry Animal Remains found at Caerwent, 1904.*—The following animal remains have been identified in the course of the excavations:—

(1) From a pot found upright in 'House XII.,' Room 39: Shrew, *Sorex vulgaris*; bird (egg-shell); toad, *Bufo vulgaris*; molluscs, *Helix pomatia* (fragment), *Helix aspersa*, *Helix rotundata*, *Helix pulchella*, *Cochlicopa lubrica*, *Limax agrestis* (?).

(2) From a drain by the side of the wall on S. side of S. gate (later extension of XIII.), 10 feet 4 inches below grass: Pig, *Sus scrofa*; teal, *Querquedula crecca* (?); fowl (?); fish-bone; iron nail.

(3) From 'House XII.,' Room 20, 6 feet down: *Achatina acicula* and *Microtus sp.*

(4) From the westernmost of two V-shaped drains between 'Houses XI. and XII.,' 5 feet down: Much Roman pottery; *Mus sylvaticus* (?); Dunlin, *Tringa alpina* (beak); teal.

(c) *Report on Wells and their Contents, 1905.*—Well A lies E. of House VI. N. (see 'Archæologia,' vol. lix. p. 112); it is 25' 6" deep; its width varies; at mouth, 2' 3" × 2' 5"; at 18 ft. down, 2' 9" × 3' 0"; at 21½ ft. down, 2' 8" × 3' 0"; and at the bottom 2' 3" × 2' 5", as at the mouth. The masonry is good throughout; the bottom is sandy rock. There is a spring at 18 feet, and here one stone is displaced. This well had already been cleared to 18 feet in 1903.

On clearing from 18 feet to 22 feet the finds were as follows: Skulls of cows and other bones of cows and sheep—all cows were poleaxed; part of the skull of a dog, and three fragments of stag-horn. From 22 feet to the bottom the finds were, more fragments of stag-horn, more skulls of cows (*B. longifrons*), oyster-shells, a scallop-shell, fragments of wood, and hoops from buckets, small twigs, an acorn, fragments of human skull (23½ feet to 24½ feet down), much Roman pottery of ordinary types, and many old shoes (not of the open-work type) with hob-nails on the soles.²

Well B lies W. of House XIII. N. It is 19½ ft. deep; its width varies: at mouth, 2' 6"; at 15 feet down, 3' 0" × 3' 3"; at bottom, 2' 4" × 2' 8". The masonry is good, but the last two feet have no masonry, the sides being of clay. The bottom is of hard gravel.

The contents were as follows: (a) from 4½ feet to 10½ feet, cow-bones, a fragment of wall-plaster, much concrete, and a little ordinary Roman pottery; (b) from 10½ feet to the bottom, cow-bones, and (at 12 feet) sheep-bones, a few oyster-shells, fragments of ordinary pottery and roof-tiles, and a few fragments of shoe-leather.

¹ See *Caerw. Comm. Report* for 1901-3 (*Archæologia*, vol. lix. 87 *seq.* and pl. ix.).

² The mud from the last four feet of the well was very difficult to examine carefully when it was actually excavated; but after it had dried, when it was used for filling in, in July of the present year (1906) five coins were found. The only legible one of these is a coin of Constans (Cohen, vol. vii. p. 431, No. 179.) Another appears to be a barbarous (British?) imitation of a Roman coin.

Samples of earth from both wells were sent to Mr. A. H. Lyell, F.S.A., who collected the plant remains; these were determined by Mr. Clement Reid, F.R.S. The smaller bones from these samples were examined by Mr. E. T. Newton, F.R.S. To all these gentlemen the cordial thanks of the Committee are due.

The following plants were identified from a sample taken from the bottom of well A:—

<i>Ranunculus acris</i>	}	. . . . .	(Buttercups).
" <i>repens</i>			
" <i>Sardous</i>			
<i>Stellaria media</i>		. . . . .	(Chickweed).
<i>Rubus fruticosus</i>		. . . . .	(Blackberry).
<i>Conium maculatum</i>		. . . . .	(Hemlock).
<i>Sambucus nigra</i>		. . . . .	(Elder).
<i>Sonchus oleraceus</i>		. . . . .	(Sowthistle).
<i>Atropa Belladonna</i>		. . . . .	(Deadly Nightshade).
<i>Prunella vulgaris</i>		. . . . .	(Self-heal).
<i>Ballota?</i>		. . . . .	(Black Horehound?).
<i>Chenopodium album</i>		. . . . .	(White Goosefoot).
<i>Atriplex</i>		. . . . .	(Orache).
<i>Polygonum aviculare</i>		. . . . .	(Knot-grass).
" <i>Persicaria</i>		. . . . .	(Persicaria).
<i>Rumex</i>		. . . . .	(Dock).
<i>Urtica urens</i>		. . . . .	(Stinging-nettle).
<i>Corylus Avellana</i>		. . . . .	(Hazel).
<i>Hordeum vulgare</i>		. . . . .	(Barley).

In the same sample the following animal remains occurred: *Helix rotundata*, *Planorbis*, *Zonites*.

The following plants were identified from samples taken from the bottom of well B:—

<i>Ranunculus acris</i>	}	. . . . .	(Buttercups).
" <i>repens</i>			
" <i>Sardous</i>			
" <i>parviflorus</i>			
<i>Senecioia Coronopus</i>		. . . . .	(Wart-cress).
<i>Raphanus Raphanistrum</i>		. . . . .	(Wild Radish).
<i>Viola</i>		. . . . .	(Violet).
<i>Stellaria media</i>		. . . . .	(Chickweed).
" <i>graminea</i>		. . . . .	(Lesser Stitchwort).
<i>Prunus spinosa</i>		. . . . .	(Sloe).
<i>Rubus fruticosus</i>		. . . . .	(Blackberry).
<i>Potentilla Tormentilla</i>		. . . . .	(Tormentil).
" <i>reptans</i>		. . . . .	(Cinquefoil).
<i>Pyrus Malus</i>		. . . . .	(Apple).
<i>Hydrocotyle vulgaris</i>		. . . . .	(Pennywort).
<i>Conium maculatum</i>		. . . . .	(Hemlock).
<i>Oenanthe</i>		. . . . .	(Water Dropwort).
<i>Caucalis Anthriscus</i>		. . . . .	(Hedge Parsley).
<i>Sambucus nigra</i>		. . . . .	(Elder).
<i>Galium verum</i>		. . . . .	(Ladies' Bedstraw).
<i>Valeriana officinalis</i>		. . . . .	(Cat's Valerian).
<i>Chrysanthemum Leucanthemum</i>		. . . . .	(Ox-eye).
<i>Arctium lappa</i>		. . . . .	(Burdock).
<i>Carduus nutans</i>		. . . . .	(Thistle).
<i>Centaurea Calcitrapa</i>		. . . . .	(Star-thistle).
<i>Sonchus oleraceus</i>		. . . . .	(Sow-thistle).
" <i>palustris</i>		. . . . .	(Marsh Sow-thistle).
<i>Solanum nigrum</i>		. . . . .	(Nightshade).
<i>Atropa Belladonna</i>		. . . . .	(Deadly Nightshade).

<i>Verbena officinalis</i>	. . . . .	(Vervain).
<i>Prunella vulgaris</i>	. . . . .	(Self-heal).
<i>Stachys sylvatica</i>	. . . . .	(Woundwort).
<i>Lamium purpureum</i>	. . . . .	(Purple Deadnettle).
<i>Chenopodium album</i>	. . . . .	} (Goosefoot).
" <i>rubrum</i>	
<i>Atriplex</i>	. . . . .	(Orache).
<i>Polygonum aviculare</i>	. . . . .	(Knotgrass).
" <i>Persicaria</i>	. . . . .	(Persicaria).
<i>Rumex crispus?</i>	. . . . .	(Dock).
<i>Urtica dioica</i>	. . . . .	} (Stinging-nettles).
" <i>urens</i>	
<i>Corylus Avellana</i>	. . . . .	(Hazel).
<i>Eleocharis palustris</i>	. . . . .	} (Sedges).
<i>Scirpus lacustris</i>	
<i>Carex</i> (four sp.)	
<i>Triticum sativum</i>	. . . . .	(Wheat).
<i>Pteris aquilina</i>	. . . . .	(Bracken).

In the same samples the following animal remains occurred: Mouse (tibia), frog (vertebra), *Limax*, *Helix* (fragments, ?*pomatia*), *Helix rotundata*, *Zonites*, *Balanus*, Roebuck (footbones), dog (ungual phalanx and tail vertebra), sheep (tooth), hare (half atlas vertebra), bird (two tibiæ), *Ostrea*, *Helix*.

The list of objects from the well in House XIII,¹ near the S. gate, is as follows. It includes small animals, but not pottery or bones of large animals, which have been kept separately in the Museum at Caerwent:—

- (a) At 13 feet 6 inches.—*Helix rotundata*; *Mytilus edulis*; charcoal.
 (b) At 15 feet 6 inches.—Fragments of bone (bank vole?), shell, and charcoal; wheat.
 (c) At 19 feet 6 inches.—Foot-bones of water vole?
 (d) At 22 feet 2 inches.—Fragment of crinoid from Carboniferous limestone: *Sus scrofa*. *Mus sylvaticus*.

<i>Vicia tetraspermum</i>	. . . . .	(Tare).
<i>Rubus fruticosus</i>	. . . . .	(Blackberry).
<i>Conium maculatum</i>	. . . . .	(Hemlock).
<i>Apium graveolens</i>	. . . . .	(Wild Celery).
<i>Aethusa Cynapium</i>	. . . . .	(Fool's Parsley).
<i>Anethum graveolens</i>	. . . . .	(Dill).
<i>Sambucus nigra</i>	. . . . .	(Elder).
<i>Galeopsis Tetralit</i>	. . . . .	(Hemp-nettle).
<i>Chenopodium album</i>	. . . . .	(Goosefoot.)
<i>Atriplex patula</i>	. . . . .	(Orache).
<i>Polygonum aviculare</i>	. . . . .	(Knotgrass).
<i>Rumex</i> sp.	. . . . .	(Dock).
<i>Urtica dioica</i>	. . . . .	(Stinging-nettle).
<i>Corylus Avellana</i>	. . . . .	(Hazel).
<i>Quercus Robur</i>	. . . . .	(Oak).
<i>Salix</i>	. . . . .	(Willow).
<i>Eriophorum polystachyon?</i>	. . . . .	(Cotton-grass).
<i>Triticum sativum</i>	. . . . .	(Wheat).

- (e) At 23 feet 10 inches (bottom):—

<i>Ranunculus repens</i>	. . . . .	(Buttercup).
<i>Brassica?</i> single seed.		
<i>Lychnis</i> .		

¹ The site is divided into two parts by the ancient (and modern) high road; and the houses to the north of it have a separate numbering from those on the south, being distinguished by the suffix N.

<i>Stellaria media</i>	. . . . .	(Chickweed).
<i>Rubus fruticosus</i>	. . . . .	(Blackberry).
<i>Conium maculatum</i>	. . . . .	(Hemlock).
<i>Athusa Cynapium</i>	. . . . .	(Fool's Parsley).
<i>Anethum graveolens</i>	. . . . .	(Dill).
<i>Sambucus nigra</i>	. . . . .	(Elder).
<i>Galeopsis Tetrahit</i>	. . . . .	(Hemp-nettle)
<i>Sonchus asper</i>	. . . . .	} (Sow-thistles).
„ <i>oleraceus</i> ?	One damaged seed	
<i>Chenopodium</i>	. . . . .	(Goosefoot).
<i>Atriplex patula</i>	. . . . .	(Orache).
<i>Polygonum aviculare</i>	. . . . .	(Knot-grass).
<i>Rumex</i>	. . . . .	(Dock).
<i>Corylus Avellana</i>	. . . . .	(Hazel).

(d) *Report on the Plant Remains for 1904.*—Mr. Clement Reid, who has kindly examined the samples of earth submitted to him, reports generally as follows¹: ‘Wheat is abundant, mixed with tares. We find also the celery and dill. The latter occurs also at Silchester. The remaining plants are weeds, such as elder, dock, and stinging nettle, with traces of willow and cottongrass, suggesting wetter places. No cultivated fruits have yet been found, the only edible species being the blackberry.’

In his report for 1905, Mr. Reid adds a general summary as follows: ‘The Roman flora of Caerwent, as far as yet known, bears a close resemblance to that of Silchester. The same introduced plants and weeds of cultivation appear at each locality, and at each there is the same remarkable absence of many of our most common recent forms; the dandelion, daisy, white dead-nettle and all the veronicas, for instance, are missing. The cultivated plants include wheat (mixed with tares) and barley, both in the state of carbonised grains, and also apple; but as yet we have none of the cultivated plums or cherries. As at Silchester, we find seeds of the deadly nightshade, common nightshade, and hemlock—as though their berries were used for some purpose—and we know that the berries of the belladonna were once commonly employed in the toilet. Of seeds used as condiments we have as yet only some badly preserved specimens, perhaps belonging to dill, a plant which has lately been identified at Silchester. Grape and fig have not yet been found. Among the weeds of cultivation we notice the tare, wild radish, star-thistle, and vervain. The two latter are interesting finds, for the star-thistle is a very local plant in Britain, and is often considered a doubtful native; whilst the vervain, much used in magic, has not before been found, and our earliest record till now was contained in the herbals.’

APPENDIX B.

Excavations on the Site of the Roman Fort known as Melandra Castle, Derbyshire, 1905.

The excavations carried out at Melandra during 1905 have had as their main results: (1) The uncovering of the foundations of the northern and southern gateways. (2) The uncovering of the greater part of the stone rampart surrounding the fort. (3) (As one result of the above) The determination of the exact dimensions of the fort. (4) A more careful examination of the rampart.

¹ The list is singularly like that of Silchester.

As the outcome of the work done: (a) Measured plans have been obtained of all the gateways except one (which is more injured than the others.) (b) A measured plan of the whole fort (including all the stone buildings discovered) has been drawn. (c) The pottery discovered on the site has been examined in detail with great care—and its bearing on the date of occupation of the camp fully brought out.

The following results of the year's work have a special bearing on the question of the occupation of the district in pre-Roman times:—

(a) In the course of the excavations, in addition to a number of Roman mill-stones, there were discovered within the area of the Roman fort a number of the earlier (beehive-shaped) querns. At least three patterns of these have been identified by Professor Boyd Dawkins, both upper and nether stones being present.

(b) An examination of the ancient roads in the immediate vicinity (by Professor Boyd Dawkins) led to the conclusion that pre-historic routes leading along Ridgeways in the direction of at least two pre-historic sites had been superseded by point-to-point Roman roads taking an easier gradient.

(c) An examination (by Professor Conway) of the set of leaden weights discovered on the site has led to a distinct confirmation of the theory (already laid down by Mr. Thomas May) that a number of these weights conform to a Keltic standard, while others are without doubt multiples of Roman units.

(d) A quantity of slag—showing the working of iron—has been found on the site. While this may not be pre-Roman, it is at least similar to what has been found on a number of pre-historic sites.

(e) A number of blunt chips and splinters, similar to those found near Rochdale and elsewhere in the Pennine Chain on Neolithic and Bronze Age sites, proves that the site was occupied in one or other or in both those ages.

Full and detailed reports of the work are contained in the volume entitled 'Melandra Castle,' published in June 1906 by the Manchester University Press.

APPENDIX C.

Excavations at Newstead, near Melrose, 1905-6.

So far, no remains of native pre-Roman civilisation have been found which require separate investigation; but there have been considerable opportunities for the examination of animal and plant remains. The animal remains, including a very large number of horse-bones, are being examined by Professor Ewart of Edinburgh and by Dr. Bryce of Glasgow. Specimens of the plant remains have been sent to the Professor of Botany at Edinburgh, and it is to further investigation of similar plant remains that the grant now made is to be applied.

APPENDIX D.

Excavations at Silchester, 1905.

No detailed report has as yet been received from the excavators as to the results obtained from the expenditure of the British Association's grant of 10 \textsterling ., which was made in 1904 for work on the contents of

wells, and for trial trenches to ascertain the relation of the town well to the rectangular street plan. But the general character of the season's work at Silchester may be gathered from the summary which follows.

The excavations of 1905 extended over the six months from May 22 to November 18, under the constant supervision and direction of Mr. Mill Stephenson.

It was proposed to complete the investigation, which was begun so long ago as 1892, of the portions of *Insulae* V. and VI., and of the unnumbered *insula* south of them, which underlie the grass field. So far as *Insulae* V. and VI. are concerned, this investigation has been completed, but owing to the unexpected depth of soil which was found overlying the buildings, in *Insula* VI., time did not allow of the ground to the south being even trenched. The excavation of the two *insulae* brought to light quite a number of interesting buildings.

In *Insula* V. the north-west corner was filled by a structure of regular plan, but uncertain use, the main feature of which was a large pillared hall or workshop, with store-rooms at the end and a corridor or portico in front. In late times the building seems to have been degraded to other purposes. South of, but detached from it, was another structure of similar plan. The chambers behind this, however, were apparently living-rooms, and give a more domestic character to the building. From this second building there extends southwards a somewhat puzzling series of chambers of several dates as far as a large edifice that occupied the south-west corner of the *insula*. The main features of this were a great hall (?) with long and short corridors facing the streets, and a narrower corridor at the further end, beyond which, again, was a square building subdivided into small rooms. The nature and object of this extensive group of buildings is under investigation. The rest of the *insula* was devoid of buildings, except along the northern margin, where there were laid open the foundations of a nice little house of the corridor type with some interesting remains of mosaic pavements.

The western margin of *Insula* VI. is mostly occupied by the major part of an L-shaped building at the north-west corner which was examined in 1892. This has now been fully traced, and proved to consist of, apparently, a series of shops covered by a corridor or colonnade along the street fronts. At the south end there has been subsequently built on a second row of chambers, apparently as a series of drying-rooms, though the hypocausts have been destroyed. The northern wing of the block is noteworthy for having been built over an extensive layer of jaw-bones of oxen.

The remainder of the north side of the *insula* is almost entirely filled with the foundations of a large mansion of somewhat interesting character. It originally consisted of a fair-sized corridor house, standing north and south, with mosaic floors. To the east of this was afterwards added a courtyard enclosed by corridors, beyond which was built a second house on a somewhat larger scale, with fine mosaic pavements, &c. A room at the south-east angle is remarkable for the remains of a wooden steeping tank sunk in the floor. In a corridor of one of the main chambers a human skeleton was found, laid in a rudely made grave against the wall. To the east of the house just described was a narrow courtyard with a wide entrance gateway on the north, and shut off from the street on the east by a strong wall.

On the southern margin of the *insula* are the remains of another

interesting house, L-shaped in plan, and forming another example of the transition from the corridor to the courtyard type. Most of its floors were of plain or patterned mosaic. Under part of this house is a wood-lined well, associated with which were a number of pieces of sawn and cut timber of various sizes and uncertain use. Another large wood-lined well was found west of the building, and a third to the north-east. From this last there led southward, apparently to carry off the overflow of the well, a carefully constructed wooden conduit made of unusually fine oaken boards; two of them were no less than 25 feet long and 3 inches thick.

Owing to the nearness of the water to the surface, comparatively few pits and wells were met with, but the contents of these have nevertheless yielded further interesting remains of plants, &c., to the patient investigations of Mr. A. H. Lyell, Mr. Clement Reid, and Mr. E. T. Newton.

Several important architectural remains were brought to light, including some pieces of turned pillars, an unfinished 'winged' altar, and a figure of a dormant lion, probably from the gable of some building.

A detailed account of all the discoveries was laid before the Society of Antiquaries on May 31, and will be duly published in 'Archæologia.'

A special exhibition of the antiquities, &c., found was also held, as in former years, at Burlington House.

It is proposed during the current year to continue, and, if possible, complete, the investigation of the grass field, other parts of which have already been dealt with in 1902 and 1904. There will then remain only one other season's work to finish the examination of the whole of the 100 acres within the town wall.

No special report has yet been received from the excavators as to the results obtained by the expenditure of the British Association's grant.

Archæological and Ethnographical Researches in Crete.—Report of the Committee, consisting of Sir JOHN EVANS (Chairman), Mr. J. L. MYRES (Secretary), Dr. A. J. EVANS, Mr. D. G. HOGARTH, Mr. R. C. BOSANQUET, Professor A. MACALISTER, and Professor W. RIDGEWAY.

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THE Committee has allotted the sum of 50*l.* to assist Dr. Evans's excavations at Knossos. Dr. Evans's report is appended.

The balance of 50*l.* was offered by the Committee to Mr. C. H. Hawes, to continue his work, begun in 1905, of measuring and describing the modern population of Crete. The grant, however, was insufficient, and Mr. Hawes was unable to accept the Committee's proposal. Application has been made for leave to retain the balance for future ethnographical work.

The Committee ask to be reappointed, with a further grant.

APPENDIX A.

Exploration at Knossos : Report for 1906.

Dr. Arthur Evans returned to Crete in April, and remained there two months, working over materials. He completed a series of tracings of the hieroglyphic and other inscribed tablets with the aid of photography, and the Italian Mission kindly allowed him to make a careful record of the inscriptions found by them in the small Palace of Hagia Triada.

With M. Gillièron's aid, Dr. Evans was able to work at some improved systems of reconstitution for the frescoes with miniature groups and of a crowned male personage in low relief.

No excavation was attempted this year, but certain works of conservation were carried out with the aid of the architect, Mr. Christian Doll. These include the support of the gypsum slabs above the cists of the Long Gallery and some necessary work in the Domestic Quarter. Various investigations were also made which resulted in the discovery of a cemetery going back to the Geometric Period, affording a new class of polychrome ware, and, on the hill west of the Palace, of remains showing the proximity of a small and very archaic Doric temple.

APPENDIX B.

Excavations at Palaikastro : Report for 1906.

Though no grant was available for further excavation at Palaikastro, it seems desirable to complete previous reports by a brief account of a small supplementary excavation which was undertaken on that site in March 1906 by Messrs. Dawkins and Droop, of the British School of Archæology in Athens.

After a few days spent in the sinking of trial trenches and pits, the excavators cleared a cave in the neighbourhood of the site known as Roussolákkos. This was entirely filled with earth containing a quantity of bones and sherds, and in the furthest recesses of the cave were found three clay *larnakes* filled with skulls, loose bones, and pottery. These have been removed to the museum at Candia. The remains belong to the period called by Dr. Evans 'Late Minoan III.,' and are the earliest of that period yet discovered, the *bügelkanne* type of vase being entirely absent. It seems unlikely that further results of importance are to be obtained from this site, as the complete clearing of the cave was made impossible by the danger of the falling-in of the roof.

Good progress has been made in preparing the results of the whole series of excavations at Palaikastro for exhibition and publication. Mr. Dawkins has spent over three months at Candia, and the Director of the British School a month and a half. The former has rearranged the Palaikastro collection in the museum : it now fills seven glass cases, not including the *larnakes* and large painted jars, which are exhibited separately.

A full account of the whole of the results from Palaikastro will be published in due course.

The Lake Village at Glastonbury.—Eighth Report of the Committee, consisting of Dr. R. MUNRO (Chairman), Professor W. BOYD DAWKINS (Secretary), Sir JOHN EVANS, Dr. ARTHUR J. EVANS, Mr. HENRY BALFOUR, Mr. C. H. READ, and Mr. A. BULLEID. (Drawn up by Mr. ARTHUR BULLEID and Mr. H. ST. GEORGE GRAY.)

THE excavations were reopened at the Lake Village near Glastonbury this year, again under the joint superintendence of Mr. Arthur Bulleid and Mr. H. St. George Gray.

Digging began on May 7, and was continued for four weeks until June 2. Two days were lost on account of heavy rain, and much inconvenience was experienced from the consequent flooding of the trenches. The percolation of water from the peat and the excavated ground of former years adjoining the digging necessitated the continual use of a pump.

The area explored covered some 580 square yards, and was situated at the N.W. corner of the village, lying to the E. and S. of the piece of ground examined in 1905.

During the digging this year another dwelling-site was discovered, hitherto unrecognised, bringing the total up to 83.

The number and variety of the 'finds' were well up to the average, and the structural discoveries were of exceptional interest and importance. Dwelling-mounds 67, 74, 76, and 83 were explored in their entirety; Mounds 68, 71, and 72, partly excavated in 1905, were completed; the larger part of Mound 73 and the N.W. quarter of Mound 75 were examined, and await completion next year. As in former seasons, numerous photographs were taken, and sectional and ground plans were made.

Mr. Clement Reid has examined and reported upon some botanical specimens sent to him while the excavations were in progress. (See end of the report.)

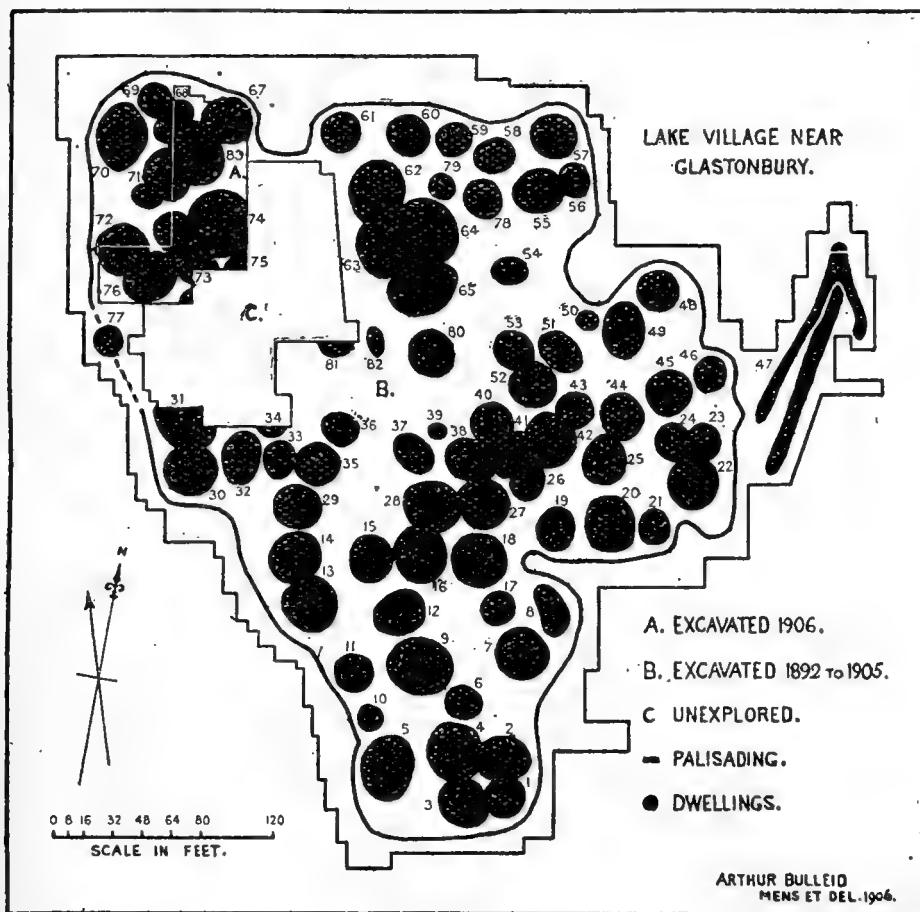
The following points of interest were noticed in the different mounds :—

MOUND 67.—This dwelling-mound was of medium size, and formed one of a group of six situated at the N.W. corner of the village, lying E. of Mound 68 and N.E. of Mound 83. It was protected along the N., N.E., and E. aspects by the border-palisading, and was composed of four floors. The greatest diameter of the mound E. and W. was 25 feet, the total thickness of clay near the centre being 2 feet 7 inches. The whole mound was tilted downwards and outwards towards the palisading on the E. of the dwelling. The substructure was strong and well preserved, especially under the E. and N.E. sides of the dwelling. The upper layers of timber were arranged in an E. and W. direction, the deeper layers being placed at right angles to these and parallel to the palisading. Thick layers of brushwood supported other parts of the dwelling-floors. Portions of an older and discarded palisading were discovered in the peat underlying the S.E. quarter of the mound. The peat situated S. of Mound 67 was composed of a heterogeneous mass of vegetable *débris*

containing chips of wood, stones, bones of animals (including the nearly complete skull of a horse), and quantities of coarse hand-made pottery.

Floor I. was composed of yellow clay, and measured 13 feet 6 inches E. and W. The hearth was well preserved, and consisted of a raised patch of baked clay measuring 4 feet 3 inches E. and W., on the surface of which a well-arranged central area of lias slabs, 3 feet 3 inches in diameter, was embedded. The hearth was much tilted towards the E., the difference in the level of the E. and W. margins being 6 inches.

Floors II. and III., which were composed of yellow clay, had no



hearths; a layer of peat and timber, 1 foot in maximum thickness, separated Floors III. and IV. in the E. half of the dwelling.

Floor IV. was composed of grey clay, and at the S.W. margin was continuous with the clay of Floor I. of Mound 83. Towards the N. and E. aspects of the mound the clay extended as far as the palisading. No hearth was discovered on this floor.

Amongst the objects of importance found in or near this dwelling were: E 248, E 249, H 338, H 339, K 30, M 18 and 19 (1895), P 133 (1895), P 173, P 176, Q 13 (1895), X 42 (1895).

MOUND 68.—This dwelling-mound was of small size, situated near the N.W. border of the village, S.E. of Mound 69, E. of Mound 70, and N.W. of Mound 83. It was protected along the N. and N.E. sides by

the border-palisading and was somewhat quadrangular in outline. It was composed of three floors, the greatest diameter of the mound being 24 feet E. and W., and the greatest thickness of clay 17 inches.

Floor I. was a small area of clay, 9 feet in diameter E. and W., with a central hearth composed of a raised patch of clay with waterworn sandstone pebbles embedded in the surface. The diameter E. and W. of the stoned area measured 18 inches, and that of the clay portion was 4 feet at the floor level.

Floors II. and III. were of greater extent, with no indications of having had hearths.

This mound contained an average quantity of pottery. Several pieces of thin grey Romano-British pottery (P 175) were found on the surface of the mound, immediately under the flood-soil, and one piece in the black earth belonging jointly to Floors I. and II.

Amongst the objects of interest from Mound 68 were : D 72, P 174, P 175, Q 48, W 179, W 180, X 50.

MOUND 71.—The greater part of this dwelling was examined and described in the 1905 report. The small section of the mound remaining along the E. side was completed. The diameter of the clay floors was 22 feet E. and W. ; the E. margin of the clay overlapped Mound 83 to the extent of 8 feet. The well-preserved and arranged timber substructure noticed last year did not reach the E. margin of the mound.

No additions were made to the list of objects enumerated last year.

MOUND 72.—This dwelling was partially excavated in 1905. It was composed of three floors and situated near the W. border of the village. Nothing particularly noteworthy was found in the construction of the mound beyond that described last year.

Among the objects found this year were : E 257, E 261, H 345, H 347, Q 49.

MOUND 73.—This was a large-sized mound, quadrangular in outline, with the greatest diameter lying N.W. and S.E. It was situated S.W. of Mound 74, S. of Mound 71, and N.E. of Mound 76. It was composed of two layers of clay, the upper being 18 inches thick at the centre and continuous at the E. margin with Mound 74, and along the W. side with Mound 76. Indications of a baked-clay hearth were noticed on the surface of the clay towards the S. part of the mound. The second layer of clay was of small extent, the greatest diameter measuring 11 feet E. and W. Time did not permit of the southern part of this mound being excavated this year, but it will, in all probability, be completed next season.

The substructure under the N. and W. aspects of the mound was not important, but under the E. side, adjoining Mound 74, it was composed of timber and brushwood placed in an E.S.E. and W.N.W. direction.

Amongst the objects of importance found in this mound were : B 346, B 402, B 403, E 245 (1905), E 259, E 260, E 262, H 346, M 40.

MOUND 74.—This was the largest mound in the N.W. portion of the village, situated S.E. of Mound 71, N.E. of Mound 73, and N.W. of Mound 75. It was composed of five floors, the greatest diameter being 34 feet E. and W., and the greatest depth of clay near the centre of the

mound 4 feet 2 inches. The floors throughout the mound were uniformly composed of yellow clay.

Floors I. and II. were the largest in extent, measuring 32 feet in diameter E. and W. Floors III. and IV. averaged 25 feet E. and W. Floor V. measured 11 feet E. and W.

The hearth belonging to Floor I. was composed of an oval area of gravel measuring 2·9 by 2·3 feet, and placed excentrically to the S.S.W. of the central picket, or highest part of the mound.

Floor II. had two superimposed hearths ; the upper, a raised area of red clay measuring 3 feet 3 inches in diameter, of a deep convex outline in section, with thirty small sandstone pebbles embedded in the centre and arranged over a space 2 feet 3 inches in diameter. The diameter of the hearth through the base was 6 feet. The lower hearth was made of grey clay.

Floor III. had two superimposed hearths ; the upper, a small area of blue clay with an unusually distinct bevelled edge ; the lower, an area of baked clay with irregular surface.

Floor IV. had a remarkable series of four hearths. The first was made of gravel with a well-defined bevelled edge of circular outline, with a diameter of 3 feet 6 inches. The second, made of grey clay, circular in outline, surface flat, and tilted towards the E. The third, made of gravel, resting on a substratum of grey clay ; the surface of the hearth was flat, the outline quadrangular, with the corners rounded off and the margin finely bevelled. The fourth, made of clay ; the surface was hard-baked and uneven, the greatest depression 3 inches deep ; the hearth had a circular outline, surrounded by a moulded rim 6 inches wide at the base and raised $1\frac{1}{4}$ inch above the level of the enclosed baked-clay area, which measured 3 feet 3 inches in diameter.

Floor V. was a small area of clay which only partially covered the timber substructure. It had two superimposed hearths of baked clay arranged excentrically W. of the central picket, or highest point of the mound

The timber substructure was remarkably complete and well-preserved. The timber formed a circular platform 19 feet in diameter E. and W., the pieces being placed lengthways in an E.N.E. and W.S.W. direction, and measured from 6 to 12 feet long and from 5 to 9 inches in diameter. These were resting on other logs placed at right angles.

The platform sank towards the centre, forming a shallow, saucer-shaped concavity, the difference in the level of the circumference and the centre of the depression being 15 inches. The platform was surrounded by several concentric rings of small piles or wall-posts. The posts were driven in at intervals of 9 to 15 inches. The inner circle of posts was placed at an average distance of 9 feet 6 inches from the centre, the second at 10 feet 6 inches, and the third at 12 feet. Besides the piles arranged in line, several hundreds more were found driven in indiscriminately, without apparent arrangement, within a distance of 12 to 16 feet from the centre of the dwelling. At the W.S.W. aspect of the platform the continuity in the lines of the wall-posts was broken for a space of 6 feet. Where the concentric circles of wall-posts terminated two lines of three large piles were found, radiating from the centre to the circumference of the dwelling. The piles in each line were placed at 12 inches apart, and the middle post in each instance formed the terminal post of the inner circle of wall-posts. Between the two lines of posts the arrangement of

timber differed completely from other parts of the substructure, and distinctly marked the entrance to the dwelling. Immediately outside the timber threshold was a large slab of lias, in the position we should have expected to find an entrance pavement. On either side of the entrance the timber of the platform was arranged triangularly; the base of the triangle, roughly measuring 5 feet, faced towards the circumference, and the apex towards the centre of the dwelling. The pieces of timber were placed parallel with the line of wall-posts, and gradually diminished in length towards the apex.

Amongst the objects of importance found in Mound 74 were the following: B 405, B 406, C 28, C 29, D 74, E 243 (1902), E 244 (1902), E 253 (1902), E 254, E 255, E 263, E 264, E 265, E 266, E 267, F 376, H 325 (1902), H 326 (1902), H 327 (1902), H 340 to H 344, H 349, H 351, H 354 to H 357, I 95 (1902), I 97 to I 102, I 105, P 177, Q 50 to Q 52, S 42, W 177 (1902), W 182, W 185, W 186, X 44.

MOUND 75.—The N.W. quarter of this dwelling-mound was partly explored, and found to be composed of four floors. The mound awaits further examination next season.

Amongst the objects of importance discovered this year were: B 407, E 268, I 106.

MOUND 76.—This dwelling-mound was situated near the W. border of the village, and was protected along the S.W. and W. aspects by the border-palisading. It was placed S.E. of Mound 72 and S.W. of Mound 73, being continuous with the floors of both the adjacent mounds. The mound was composed of three floors, the greatest diameter E. and W. being 32 feet. The greatest depth of clay near the centre of the dwelling was 2 feet.

Floor I.—The hearth was incomplete, being within a few inches of the surface of the field. It was composed of a circular area of red marl 3 feet 6 inches in diameter.

Floor II.—The hearth belonging to this floor was made of a raised area of clay 3 feet 3 inches in diameter, with thin slabs of lias embedded at the centre. The diameter of the stone-work measured 2 feet.

Floor III. was made of a mixture of grey marl, yellow clay, and fire-ash, having quite a different appearance from the floors above made of yellow clay. The hearths belonging to this floor were composed of grey marl, and arranged in three superimposed layers. The centre of the upper hearth was hollowed out in the shape of a shallow basin with irregular outline, the depression in section being bordered by a raised moulded rim averaging 7 inches in width across the base and $2\frac{3}{4}$ inches in depth. The depression was filled with fire-ash and several fragments of slag. Pieces of slag were also found on the floor around, together with portions of two crucibles and fragments of bronze and iron.

The substructure was strong and well-preserved along the S.W. and W. aspects of the mound, the timber being chiefly arranged in a N.N.W. and S.S.E. direction, with occasional planks placed at right angles. Under other parts of the mound the woodwork was of less importance.

Amongst the objects of importance found in Mound 76 were: C 26, C 27, B 224 (1895), B 404, E 256, E 258, H 348, H 350, H 352, H 353, I 96, M 14 (1895), P 178, W 81 (1895), W 183, W 184, X 43.

MOUND 83.—This dwelling-mound covered a large area, measuring

28 feet E. and W. It was situated near the N.W. corner of the village, lying S.W. of Mound 67, E. of Mound 71, and S. of Mound 68. It was composed of four floors, the margins of which were considerably overlapped by the three adjacent mounds. Floors I., II., and III. were made of pale yellowish-grey clay; Floor IV. of yellow clay, in which quantities of hard orange-coloured ochreous nodules and gravel were uniformly mixed. The greatest thickness of clay at the centre of the mound measured 3 feet 6 inches.

Floor I. was a thin layer of clay with an average thickness of 6 inches; there were distinct traces of a baked-clay hearth extending over a circular area 5 feet in diameter.

Floor II. was 8 inches thick at its greatest depth, and near the centre there were indications of a baked-clay hearth.

Floor III.—The clay averaged 6 inches thick; the hearth was made of baked clay, and measured 2 feet 11 inches E. and W. across the top.

Floor IV.—The clay of this floor was 1 foot 10 inches thick at its greatest depth. The hearth was a circular area of baked clay, having a well-preserved and finely moulded bevelled edge averaging 2 inches in depth. The average diameter across the top was 3 feet 7½ inches; the centre was raised 2 inches above the periphery of the edge and from 3 to 5 inches above the marginal line of the base.

The substructure was not strong or well arranged. Lying parallel with the E. margin of Floor IV. a large mortised oak beam with three perforations was unearthed, measuring 8 feet long and 15 inches wide: it did not appear to be in its original position. Along the N.E. margin of the mound a line of hurdle-work was found, lying in a N.N.W. and S.S.E. direction. An alder-tree stump with roots *in situ* was found in the peat under the N.W. quarter of the mound.

Amongst the more important objects found in this mound were: D 73, E 250 to E 252, F 374, F 375, F 377, H 336, H 337, L 39, W 181.

SHORT DESCRIPTION OF THE RELICS; ALL FOUND IN 1906, UNLESS OTHERWISE STATED.

Bone Objects. (B.)

224. Large needle; found in the peat outside the palisading to the W.S.W. of Mound 76, 1895.

346. Unfinished needle, length 57 mm. N. edge of Mound 73.

402. Large needle, probably used in net-making, made from the upper end and greater part of the shaft of the right tibia of a young sheep(?); length 147 mm. It has a smooth, blunted point; the upper end of the bone is perforated transversely, the circular hole on each side being 4 mm. in diam. Mound 73.

403. Half a polished metatarsus of sheep or goat, with circular perforation 6 mm. in diam. at the upper end. An incipient hole is seen on one side in the middle of the shaft, close to the point where the bone has been fractured. Mound 73.

404. The greater part of a polished metatarsus of sheep or goat, with condyles cut off at the distal end; at the proximal end a circular hole (diam. 9 mm.), and another smaller at the side, close to the end. Mound 76. Perhaps used as a kind of shuttle-spool in weaving. (See similar object figured in 'Proc. Som. Arch. Soc.,' vol. xlviii. pt. 2, p. 113, fig. 20.)

Six other perforated metatarsals, mostly broken, were also found this year (one from Mound 73, four from Mound 74, and one from Mound 76); also one perforated metacarpal, Mound 73.

405. Short, stout needle, made apparently from bird bone; length 485 mm. The head is roughly oval and flat, and 7·2 mm. in max. width; the eye is of an irregular oval form, 4 mm. long. Mound 74.

406. Piece of highly polished bone broken at one end; length 52·7 mm. On one side, near the complete end, is a perforation of elongated oval form (length 10 mm.), slightly pinched in at the middle. Mound 74.

407. Portion of the shaft of a tibia of horse (?), sawn transversely at one end. Mound 75. It may be part of one of the objects described under B 382 in last year's report.

Distinct knife-cuts on five portions of rib-bones were found this year (three in Mound 74, one in Mound 76, and one in Mound 83).

A smaller proportion of bone objects was found this year than usual.

Crucibles. (C.)

26. One corner of a triangular hand-made, grey crucible. A small piece of bronze was found within a foot of it. Mound 76.

27. A similar piece to the last, with a little bronze adhering to the interior surface. Mound 76.

28. Portion of a thick crucible (max. thickness 20 mm.) with bronze adhering to the inner surface. Mound 74.

29. Fragment of the base of a crucible. Mound 74.

Baked Clay. (D.)

72. Small piece of baked clay with three arms; perhaps a toy, or a 'stilt' used in the process of firing pottery. Mound 68.

73. Smooth, semi-globular piece of baked clay, the flat side being scored with slight incisions; diam. 33·5 mm. Mound 83.

74. Disc of baked clay, 24·5 mm. in diam., of bi-convex section, max. thickness 11 mm. It is too small for an unfinished spindlewhorl; it may have been intended for use in a game, or as a counter. N.N.W. of Mound 74.

Sling-bullets.—One in Mound 67, one Mound 73, three Mound 74, three Mound 76, and one of small size in trenching S.E. of Mound 83.

Loom-weights.—Triangular loom-weight and portions of others in Mound 73.

Bronze Objects. (E.)

243. Rivet-head, diam. 15 mm. Mound 74, 1902. † (Figured in 'Proc. Som. Arch. Soc.' vol. xlviii. pt. 2, pl. iii. fig. 2.)

244. Small fibula, length 34 mm., with spring of coiled wire 1·3 mm. thick. Like other fibulae of this class, it has been formed from one piece of metal, with the exception of the axis, which passes through the cylindrical space enclosed by the coils. The spring, beginning from the bow, makes five twists outwards on one side, then arches over the back of the coil and completes five turns inwards. The summit of the bow is of circular section (diam. 4·3 mm.). The catch-plate is not perforated in this example, and it is somewhat clumsy in proportion to its total length. The flat face of the catch-plate is decorated merely by an oblique incised line, which joins, on the bow of the fibula, two transverse grooves—an ornamental survival of the bands or collars which originally served the useful purpose of fastening the retroflected ends of the bows of fibulae. Found in Mound 74, 1902. (Figured in 'Proc. Som. Arch. Soc.' vol. xlviii. pt. 2, pl. iii. fig. 1). Other fibulae of this type have been found in the Village—viz., E. 5, 22, 26, and 158.

248. Rivet-head, diam. 12 mm., height 6 mm. The rivet, diam. 2 mm., projects 0·8 mm. below the base of the head. Mound 67.

249. Two pieces of thin bronze plate, 43 and 45 mm. respectively in length. One piece has a small rivet-hole. Mound 67.

250. Piece of bordering, length 28 mm. S.E. of Mound 83.

251. Solid bronze link-shaped object, consisting of a stem of circular section tapering both ways and joining two circular flat ends (10·3 to 11·5 mm. in diam.);

length of object 26.4 mm.; weight 245.2 grains. On one side of the stem is a ring or link, 13.5 mm. ext. diam.; on the opposite side of the stem is a raised circular ornament, enclosed by a narrow beading. Found in the peat to the S.E. of Mound 83. A similar 'link'—E 92—was found in the Village, near the margin of Mound 27 in 1895.

252. Fibula, incomplete, the head being deficient; it consists of a continuous piece of wire averaging 2 mm. in diam. The coiled spring, beginning from the bow, makes two twists outwards on one side, and, arching over the back of the coil, completes two twists inwards, continuing to form the pin. S. of Mound 83.

253. An ovoid lump, apparently of bronze dross, length 45.5 mm.; max. diam. 24.5 mm. Mound 74, 1902. ('Proc. Som. Arch. Soc.' vol. xlviii. pt. 2, p. 109.)

254. Needle, length 68 mm.; in a good state of preservation, except that it has been slightly bent by a knock from the workman's spade. It has been flattened out near the top to provide sufficient width (4.1 mm.) for the boring of the eye, which is of fusiform outline, 6 by 2 mm. The top of the eye is 7 mm. from the upper end of the needle. N.W. of Mound 74. A similar needle—E 43—was found in Mound 42, 1894.

255. Rivet-head, diam. 11 mm., height 6.5 mm., with the usual rivet in position. N.W. of Mound 74.

256. Two fragments of bronze dross. Mound 72.

257. Small rounded piece of bronze, incomplete, width 11 mm. It appears to have had perforations in two directions. Mound 72.

258. Small piece of bronze, not worked. Mound 72.

259. Penannular ring-brooch, composed of wire averaging 1.3 mm. in diam.; int. width of ring 19 mm. The ends terminate in spirals of nearly three turns, the wire gradually tapering towards the end. One of the spiral coils is broken; width of opening between the spirals 7.5 mm. Ext. width of brooch at spirals 25 mm. The plain arched pin is in position, length 29.5 mm. Mound 73. Six other ring-brooches of this character have been found in the Village, viz., E 23, 42, 61, 103, 161, and 176.

260. Portion of a rivet-head, rather above the average in size. Mound 73.

261. Small piece of flattened bronze with a bevelled edge, probably one of the ends of a pair of tweezers. Mound 72.

262. Harness ornament, complete, but somewhat corroded. It consists of two conjoined discs, each 20.5 mm. in diam. Both discs are bored centrally by holes about 5.5 mm. in diam., converting them into a figure "8" design. The discs are concavo-convex in section; their concave faces may have been filled with enamel; the convex face is ornamented round the middle of each of the conjoined rings by little circles in relief (diam. 2.5 mm.) enclosing small depressions—in fact, a dot-and-circle pattern. The discs are not only joined centrally to form an 8-shaped design, but the broadest part of the upper and lower halves of the 8 are connected vertically by a bar on either side (of circular section, diam. 3.3 mm.), round which leather strap-ends would be attached. Each bar terminates in flat stops 9 mm. in diam. at the point where the bars are connected with the 8-shaped centre of the object. Max. height of the ornament 38 mm.; max. width 36 mm. Mound 73. A harness ornament of somewhat similar character and design was found with other Late-Celtic objects in General Pitt-Rivers's last excavations at Park House Farm, Iwerne, Dorset, 1897.

263. Piece of much-corroded thin bronze, attached to wood by means of two bronze rivets 2.5 mm. in diam. Mound 74.

264. Solid finger-ring, complete, ornamented by a deep continuous groove round the middle. Int. diam. 16 mm.; width of ring at front 5 mm., tapering to 3.3 mm. at back; bi-convex cross-section. Mound 74.

265. Spiral finger-ring, the coil completing three and a half circles or turns. The wire from which it was made is of flattened oval section, 3 by 1.3 mm. (it tapers, however, towards the ends); max. width of ring 12 mm.; int. diam. 16 mm. Mound 74. Over a dozen similar rings have been found in the Village from time to time, but none more perfect than that under consideration.

266. Apparently a piece of bronze dross. Mound 74.

267. Portion of a band of thin bronze plate, width 32.5 mm., with rivet-holes (diam. 2 mm.). Mound 74.

268. Corroded lump of bronze with charcoal adhering. Mound 75.

Flint. (F.)

374, 375, and 377. Three finely-worked scrapers. Mound 83. Two other scrapers were found in this mound.

376. Part of a scraper. Mound 74.

A large roughly chipped scraper was found amongst the piles of the border-palising below the clay, S.E. of Mound 67.

A good specimen of a flint core was found in Mound 72; another in Mound 76; and a burnt flint in Mound 73.

Flint Flakes.—One with secondary chipping, Mound 67; three in Mound 68; one with secondary chipping, Mound 72; five in Mound 73; five in Mound 74 (also a rough flint knife); eight in Mound 76 (one with secondary chipping); seven in Mound 83 (one with secondary chipping).

Antler. (II.)

325. Unusually long weaving-comb, found in seventeen fragments; length 219 mm. ($8\frac{5}{8}$ inches); max. width 41 mm. ($1\frac{5}{8}$ inch). The handle-end, which has been roughly cut off square, has a hole for suspension. There were originally ten teeth, averaging 25 mm. in length. Near the dentated end the comb is decorated with incised dots and circles in fourteen places without any systematic arrangement. Mound 74, 1902. (Figured in 'Proc. Som. Arch. Soc.,' vol. xlviii. pt. 2, pl. iii. fig. 4.)

326. Portion of the handle-end of a weaving-comb, in two pieces, which do not join. The hole for suspension is countersunk on the face of the comb. The upper part is ornamented with two transverse lines and one oblique incised line, and the smaller fragment with a circular depression with a small hole in the centre; this decoration was probably produced by means of a centrebit. Mound 74, 1902. (Figured in 'Proc. Som. Arch. Soc.,' vol. xlviii. pt. 2, pl. iii. fig. 5.)

327. Portion of a weaving-comb which probably had nine teeth originally; it is very smooth, owing to prolonged use. The decoration consists of roughly incised transverse lines. Mound 74, 1902. (Figured in 'Proc. Som. Arch. Soc.,' vol. xlviii. pt. 2, pl. iii. fig. 6.)

336. Upper end of an ornate weaving-comb with squared top and a circular hole for suspension (diam. 5 mm.). It was ornamented by double incised oblique and transverse lines; just below the hole is an ornament consisting of two deeply incised concentric circles with a depressed dot in the centre. Mound 83.

337. Much-weathered weaving-comb with squared top and hole for suspension (diam. 7 mm.); length from top to upper margin of the broken teeth, 143 mm. It originally had eight teeth. Two representations of the dot-and-circle pattern are still observable at the top. Mound 83.

338. Piece of worked antler, with raised band at one end, ornamented with one transverse line. It may probably be portion of the handle of a weaving-comb. S. of Mound 67.

339. Portion of a well-preserved red-deer antler, sawn, having a polished tine; length 157 mm. S.S.E. of Mound 67.

340. Portion of a large weaving-comb, found in several fragments; length 109 mm.; max. width at dentated end 41 mm. The handle was ornamented by crossed oblique lines, forming diamonds. It originally had nine teeth, of which five remain complete; they average 21 mm. in length. Mound 74.

341. Point of a tine, length 75 mm., exceedingly smooth from prolonged use. Perforated by three holes, the centres of the two upper ones being 12 mm. apart, the central one and the lower being divided by a greater distance—viz. 16.5 mm. The hole nearest the point is rather larger and not so round as the other holes. Between the squared end and the first hole the object is encircled by three incised lines, much worn down by perpetual friction. The precise use of the object is not known, but it is complete. N.W. of Mound 74.

342. Weaving-comb in process of manufacture; length 142 mm.; max. width across the dentated end 44 mm. The ten teeth (length 27 mm.) have not been sharpened, and the spaces between them have only been roughly cut, probably with a knife (not a fine saw). There is no decoration on the handle and no hole for suspension. Mound 74.

343. Tine of roe-deer antler, length 145 mm., worked at one end to a very smooth point; the other end has been sawn off square and perforated longitudinally; this aperture meets a transverse hole bored on one side of the antler 13 mm. above

the base. Perhaps used in decorating pottery; the holes probably for suspension, Mound 74.

344. Hammer of red-deer antler, the handle consisting of the brow tine, the hammering end being represented by the burr; length 220 mm. ($8\frac{5}{8}$ inches). The base of the bez tine remains and forms part of the back of the hammer. At this point the antler has been sawn through transversely. The circumference of the antler midway between the brow and bez tines is 174 mm. The handle was found broken in many pieces, but has now been almost completely restored. Mound 74.

345. Fragments of smooth antler, calcined. Mound 72.

346. Tine of red-deer antler, measuring 260 mm. in length along the outside curve. It has the appearance of having been 'stabbed' over the greater part of its surface by deep, irregular incisions, the purpose of which is unknown to the writers. Mound 73.

347. Piece of worked but much decayed red-deer antler; length 215 mm. S.W. of Mound 72.

348. Small worked antler, length 190 mm. The base is rounded and is slit, as if intended to receive the base of the blade of a knife. There are, however, no rivet-holes; the slit is 35 mm. long. The upper tine has been worked to a smooth, flat point; the two other tines have had their points removed and have been countersunk for the purpose of ornamenting pottery with indented circles about 4 and 6 mm. in diam. Mound 76.

349. Tine of red-deer antler, length 142 mm., sawn square at the base; the point has been smoothed, but both ends are now somewhat disfigured by teeth-marks caused by gnawing. Mound 74.

350. Shaft of a plain weaving-comb with oval enlargement at the handle-end, but no perforation; length 130 mm. All the teeth, which were originally thirteen in number, have been broken off. Mound 76.

351. Hammer-head made from the base of a large red-deer antler, found unbroken; length on the upper ext. curve 145 mm. Both the brow and the bez tines have been sawn off. The minimum circumference of the antler midway between the deficient tines is 195 mm. The transverse hole of oblong section (32 by 21 mm.) for the wooden handle runs in a line parallel to the face of the burr. The latter shows much evidence of prolonged use, and the sides of the hammer-head are 'pecked' to a considerable extent. Mound 74. Similar hammers have been previously found in the Village, one (H 171) being figured in 'Proc. Som. Arch. Soc.,' vol. 1. pt. 2, pl. viii.

352. Weaving-comb in a bad state of preservation and much broken, the dentated end beyond repair. The top of the handle is squared and perforated with the usual hole (diam. 5 mm.) Between the hole and the top is a double band of ornament of crossed oblique lines; the same kind of decoration occurs just over the teeth. Mound 76.

353. Piece of worked red-deer antler showing knife-cuts. Mound 76.

354. Curved knife-handle composed of a worked tine of red-deer antler of tapering oval section. The bottom of the handle measures 15.5 by 11.3 mm., the point of the tine having been cut off; the other end measures 32.5 by 24 mm. The base of the tang of the iron knife, secured by two iron rivets, still remains in position, being let into a slit in the handle for a depth of 32.5 mm. on the outside curve of the antler. Length of handle along outside curve 258 mm. ($10\frac{1}{8}$ inches). Mound 74. A few similar knife-handles have been discovered in the Village, but none in better preservation than the specimen under consideration.

355. Portion of a weaving-comb with short teeth, of which the greater part of five remain. Decorated with four dots and circles. Mound 74.

356. Ornamental weaving-comb, length 148 mm. The handle end is squared off, one corner having been gnawed by a dog; the perforation for suspension, however, is complete, diam. 6 mm. Five of the ten teeth remain, the longest measuring 21.5 mm.; max. width at dentated end 41.5 mm. The transverse, oblique, and zigzag grooves with which the shaft is decorated have been roughly cut; but the comb is much polished from prolonged use. Mound 74.

357. Portion of an unknown object of red-deer antler; length in a straight line 182 mm.; max. width 45.5 mm.; section concavo-convex. On two sides and one end it has been carefully sawn; the other end is broken. The face of this broad antler has been smoothed to a certain extent; near the top and bottom are two rather deep transverse saw-cuts, and near the middle of the object a circular depression (not a perforation) 7.5 mm. in diam. Mound 74.

Iron. (I.)

95. Horse's snaffle-bit, much corroded and in three parts. It is seen that the pair of 'links' forming the greater part of the bit are connected in the middle by an iron ring, and that on the outer sides portions of large iron rings, to which the bridle was attached, adhere by corrosion. Mound 74, 1902.

96. Small gouge, fractured through the shaft and broken off at the head of the tang of quadrangular section. The shaft is of circular section, approx. diam. 7 mm. The gouge has a deep curve and is 10 mm. wide at the cutting edge. Mound 76.

97. Portion of a thin knife or dagger, length 87 mm. Mound 74.

98. Small file, pointed at both ends, length 82 mm.; max. width 7.5 mm. The file-markings are at right angles to the length of the tool, and there are about twenty-eight grooves and twenty-eight ridges to the inch. Mound 74. A small file with forty grooves and ridges to the inch (I 47) was found in Mound 42, 1895. Larger files have been found in the Village. (See I 102.)

99. Three portions of blades of knives, found close together in Mound 74.

100. Large curved, tanged knife, perhaps used for cutting up meat. Total length in a straight line 279 mm. (11 inches). Single-edged blade, the edge being convex and strongly curved; the back convex and 5.5 mm. thick towards the base; max. width of blade 53 mm.; the tip is deficient. The tang, which has an iron collar at the top, is of quadrangular section and 90 mm. long; the bottom, however, is deficient. Mound 74. No similar blade has been found in the Village.

101. Small pointed implement in two pieces. Mound 74.

102. File of quadrangular section, pointed at both ends; badly corroded; length 155 mm. ($6\frac{1}{8}$ inches). The transverse ribbings of a fairly coarse file are seen on one face, and others are barely traceable on the three other faces also. Max. width in middle 10 mm. Mound 74. Similar files have been found in the Village, viz. I 3, I 81, and I 84.

105. Blade of a narrow curved knife, max. length 111 mm. in a straight line; average width of blade 15 mm. As in the case of the heavy knife (I 100), the cutting edge is on the convex side, the concave back being 2.5 mm. in thickness. Mound 74.

106. Four pieces of nondescript iron, all of quadrangular section, one piece having a tang; perhaps parts of the same implement, but they do not join. Mound 75.

Several large pieces of iron slag were found in round cakes in Mounds 71 and 76.

Kimmeridge Shale. (K.)

30. A large armlet (or anklet?) in three pieces; although they complete the ring, a fairly large piece of the shale has been flaked off on both faces. Ext. diam. 109 mm. ($4\frac{1}{4}$ inches); int. diam. 82 mm. It is therefore larger than the similar complete armlet (K 29) found last year, which is 97 mm. in ext. diam. (Figured in 'Proc. Som. Arch. Soc.', vol. li. pt. 2, p. 97.) K 30 is ornamented by a deep continuous groove (width 2.5 mm.) round the middle of the external surface of the armlet, bounded on either side by a rounded ridge, and again by a much slighter groove. The ring is of oval section, 13 by 15 mm. This armlet affords another excellent example of the skill of the Lake-dwellers in using the lathe. At the points of fracture no less than four attempted reparation-holes are observable; the drilling or boring caused portions of the armlet to split or flake, as mentioned above, after which the pieces were evidently thrown aside in disgust, the attempted repairs having failed. The pieces were found in Mound 67 within 2 or 3 feet of one another.

Lead and Tin. (L.)

39. Small flat whorl, apparently of lead, with flat faces, diam. 19 mm. The circular hole (min. diam. 8 mm.) is bevelled on both faces. Mound 83.

Human Bones. (M.)

14. Human skull, nearly complete; also an atlas close to. Found outside the palisading near the S.W. side of Mound 76, 1895.

18. Vertebra, fractured. Found outside the border-palisading to the N.E. of Mound 67, 1895.

19. Complete human skull and jaw. Found outside the border-palisading N.E. of Mound 67, 1895. The skull had a tranverse cut across the occipital bone, which was found lowermost when discovered.

40. Several fragments of human skull. Mound 73.

Animal Bones. (N.)

A great quantity of animal remains was collected from the 1906 excavations, including a small skull of horse and a skull of *Bos longifrons* found in the peat outside the palisading to the W.S.W. of the centre of Mound 76; it belonged to an animal about the height of our Alderney cow (3 feet 10 inches at shoulder). Two or three jaws of cat were found in Mound 74; and in Mound 73 a piece of bone gnawed by a dog.

Pottery. (P.)

133. Ornamental pottery. Found outside the palisading N. of Mound 67, 1895.

173. The greater part of an ornamented globular bowl, height 5 inches, ext. diam. at rim $5\frac{3}{4}$ inches, max. ext. diam. $6\frac{3}{4}$ inches. Ornamented with a band of decoration (width $2\frac{1}{4}$ inches) just below the rim, consisting of rows of chevrons, pointing downwards, filled with crossed lines parallel to the sides. On one side near the base are three perforations (diam. 6 inches), triangularly arranged, probably intended for straining honey. Mound 67.

174. Rim and base of a globular bowl, found in many fragments. On the bulge of the vessel is a band of decoration (width $1\frac{1}{2}$ inch) in characteristic Late-Celtic style, of double-lined wave pattern, with indented dots and circles between the lines at intervals of from $1\frac{3}{4}$ to $2\frac{1}{4}$ inches apart. Mound 68.

175. Fragments of the base (diam. $2\frac{5}{8}$ inches) of a Roman vessel of thin, hard, lathe-turned grey ware, found scattered about at the base of the 'flood-soil' covering Mound 68, one piece being found in the black earth belonging jointly to the first and second floors. It is quite probable that these fragments belong to the same pot as the pieces of grey ware represented by 'finds' P 132 (1895) and P 166 (1905); indeed, parts of P 132 and P 166 have now been found to join.

176. The greater part of an ornamented hand-made pot, found in three large pieces. The sides are slightly convex, but the rim is decidedly incurved. Height of vessel $5\frac{3}{4}$ inches, ext. diam. at rim $5\frac{1}{4}$ inches, max. diam. 6 inches, diam. of base $3\frac{1}{2}$ inches. In the middle of the base is a large rounded hole, probably for straining honey from the comb. S. of Mound 67.

177. Handle or loop of a hand-made pot with cylindrical aperture 11 mm. in diam.; width of projection 12 mm. W.N.W. of Mound 74. Handles of pots are rare in the Village.

178. Fragment of a rim (depth $2\frac{1}{2}$ inches) of a large pot; probably the deepest rim found in the Village. Mound 76.

A large quantity of fragments of pottery was found, all of which has been preserved, as in previous years. As was the case in 1904 and 1905, the number of ornamental fragments was below the average. One ornamental, almost straight-sided, fragment, found to the S.E. of Mound 83, has three cordons in rather slight relief, reminding one of the vases from the Aylesford urn-field ('Archæologia,' vol. lii.). All the decorated pottery has been repaired, and some of the designs will be figured eventually. Much pottery was found to the S.E. and E.S.E. of Mound 83, including the base and side of a heavy plain pot (height $5\frac{3}{8}$ inches, diam. at base $4\frac{1}{2}$ inches) and the base of another (diam. at base 4 inches).

Querns. (Q.)

13. Complete upper stone of a quern. N.W. margin of Mound 67, 1895.

48. Lower stone of a circular quern, imperfect, having two convex surfaces, one convexity being more pronounced than the other; max. thickness $7\frac{1}{2}$ inches. There is a hole on both surfaces, one depth $2\frac{1}{4}$ inches, the other $2\frac{3}{8}$ inches. More than half of each hole remains, and, viewed from the side of the fracture, it is seen that the holes are not in line by an inch. Both holes are about 2 inches in diam. at the mouth. Mound 68.

49. Part of the upper stone of a quern. Mound 72.

50. Upper stone of a quern, max. diam. 15 inches. Smooth on concave under-surface. The concavity deviates from a straight line to a depth of $1\frac{3}{8}$ inch. Max. diam. of central aperture $3\frac{1}{2}$ inches. One of the handle-holes has been broken; it was $2\frac{3}{4}$ inches wide and $3\frac{1}{4}$ inches deep. There is another handle-hole on the other side of the quern, measuring about 3 inches by 2 inches at the mouth, where some of the stone is now deficient. Mound 74.

51. Upper stone of quern in fragments. Mound 74.

52. Lower stone of quern in fragments. Mound 74.

Stone Objects. (S.)

42. Smooth sandstone disc, almost circular, diam. 50 mm.; max. thickness 11 mm.; bi-convex in section. It may be an incomplete spindle-whorl. Mound 74.

Small rounded Pebbles, probably 'calculi.'—One from Mound 67; two from Mound 71; two from Mound 74.

Whetstones, mostly having slightly convex faces.—One from Mound 68; two from Mound 72; four from Mound 74; one from Mound 76.

Other stone objects.—Hammerstone, Mound 72; two hammerstones, Mound 74.

Spindle-whorls. (W.)

81. Spindle-whorl, found in the peat outside the palisading S.W. of Mound 76, 1895.

177. Spindle-whorl of indurated sandstone of Devonian age in process of manufacture (diam. 41 mm.), with excentric incipient hole; round this hole a ring has been faintly scratched in a more central position than the hole itself; the ring was probably indicated to correct the faulty commencement of drilling the hole. It was evidently the intention to finish the hole by 'pecking' instead of by drilling, by which method the position of the hole could be properly adjusted. Mound 74, 1902.

179. Sandstone disc with flat faces and straight sides; probably an incomplete spindle-whorl; diam. 38.5 mm.; thickness 10 mm. Mound 68.

180. Rough sandstone disc, of an irregular oval form, with flat faces and an incipient hole for the purpose of making a spindle-whorl. Max. diam. 41 mm.; thickness 9 mm. Mound 68.

181. Rough sandstone disc, probably a spindle-whorl in an early stage of manufacture; diam. 53 mm. It varies considerably in thickness. S.W. of Mound 83.

182. Stone disc, bi-convex in section, but flatter on one side than the other; max. diam. 47 mm.; max. thickness 17 mm. Probably a spindle-whorl in an early stage of manufacture. Mound 74.

183. Large flat sandstone spindle-whorl; diam. 52 mm.; thickness 10 mm. The hole, which is somewhat excentric, is 6.5 mm. in diam. Mound 76.

184. Spindle-whorl made from the base of a black earthenware pot which was decorated on the bottom. The whorl is not quite circular, the diameters varying from 49 to 52 mm. The perforation for the reception of the wooden spindle is 9 mm. in diam. externally. Thickness of whorl 10 mm. Mound 76.

185. Thick sandstone spindle-whorl with flat faces and straight sides; diam. 44 mm.; thickness 15.5 mm.; diam. of hole 6.5 mm. Mound 74.

186. White lias spindle-whorl in a decomposed and friable condition; flat faces and straight sides; diam. 35.5 mm.; thickness 10 mm.; diam. of hole 4 mm. Mound 74.

Miscellaneous.

Red colouring matter was found in Mound 76.

A *Gryphæa incurva* was found in Mound 74.

Wooden Objects. (X.)

42. Wooden mallet with handle complete; max. length of head 7 inches; max. width of head 3.85 inches; diam. of perforation for handle $1\frac{1}{8}$ inch; handle 11 inches long. Found in the peat outside the palisading to the N.N.W. of Mound 67, 1895.

43. Portion of hub of a wheel measuring 13 inches long, the diam. of the hub when complete being $5\frac{1}{4}$ inches. Mound 76.

44. Wooden ladle, found in several fragments. Mound 74.

50. Piece of cut wood, max. length $6\frac{7}{8}$ inches; average thickness 2.45 inches, half-notched at middle-third, with peg through centre of notch. Found in the peat under Mound 68.

Botanical Specimens.

From peat under Mound 67.—*Corylus avellana* (hazelnut); *Fontinalis* (floating moss); *Carex riparia*? (sedge).

Mound 72, from bottom floor.—*Pisum sativum* (cultivated pea); *Triticum sativum* (wheat); *Hordeum vulgare* (barley); *Corylus avellana* (hazelnut).

Mound 72, from third-floor level, but a little to the W. of the mound.—*Iris pseudacorus* (yellow flag).

There are others not yet identified.

The Ductless Glands.—*Second Interim Report of the Committee, consisting of Professor SCHÄFER (Chairman), Professor SWALE VINCENT (Secretary), Professor A. B. MACALLUM, Dr. L. E. SHORE, and Mr. J. BARCROFT. (Drawn up by the Secretary.)*

The Nature of the 'Islets of Langerhans' in the Pancreas.

THE majority of writers, especially among pathologists, look upon the 'islets of Langerhans' as constituting a tissue, *sui generis*, bearing little or no relation (except perhaps a similarity of embryonic origin) to the zymogenous tubules of the gland. The present investigation tends to show that this view, which has already been challenged by Dale, is not the correct one.

The 'islets' are in all animals in direct continuity with the zymogenous tissue, and all kinds of transition forms are frequently to be met with. In mammals it is often difficult to detect any line of demarcation between tubules and islets, and this is even more difficult in birds, reptiles, and lower vertebrates generally.

In birds and reptiles a lumen can often be detected in the cell columns of the islets. This applies also to some teleostean fishes.

Moreover the intimate relation between zymogenous tissue and islets is shown by the fact that it is possible to convert zymogenous tissue into islet by exhaustion and inanition. In the latter case the islet tissue is reconverted into zymogenous when the animal is restored to its normal condition. This interchangeability has been noted in mammals, birds, and amphibians.

The study of the pancreas in birds and reptiles revealed the presence of a third kind of tissue in the vertebrate pancreas which seems not to have been previously described. This is most typically seen in the two groups mentioned, though its presence has been verified in other groups also. The tissue stains deeply with ordinary staining reagents, and therefore the name 'bathochrome' is suggested for it, while in contrast we may call the known 'islets of Langerhans' 'leptochrome,' since these stain less deeply than the surrounding zymogenous tissue. The nature of the bathochrome tissue and its relations to the other constituents of the organ are at present under investigation.

A full account of the results so far obtained will be published in the 'Internat. Monatsschr. f. Anat. u. Physiol.'

The Effect of Climate upon Health and Disease.—*Report of the Committee, consisting of Sir T. LAUDER BRUNTON (Chairman), Mr. J. BARCROFT (Secretary), Colonel D. BRUCE, Dr. A. BUCHAN, Dr. F. CAMPBELL, Sir KENDAL FRANKS, Professor J. G. MCKENDRICK, Sir A. MITCHELL, Dr. W. C. F. MURRAY, Dr. PORTER, Dr. A. J. WRIGHT, and the Heads of the Tropical Schools of Liverpool and London.*

In the following complete list of the members of this Committee the names of those attached to the Committee for purposes of consultation and reference are indicated by an asterisk :—

- *Aldridge, Major A. R., R.A.M.C., Simla, India.
- *Allbutt, Prof. T. Clifford, F.R.S., Cambridge.
- *Anderson, Dr. Barcroft, East London.
- *Ashe, Dr., Kimberley, Cape Colony.
- *Atwater, Prof., Middletown, U.S.A.
- *Balfour, Prof., Khartoum.
- *Benedict, Prof., Middletown, Conn., U.S.A.
- Bohr, Prof., Copenhagen.
- Bruce, Col. D., C.B., F.R.S., London.
- Buchan, Dr. A., F.R.S., Edinburgh.
- *Bumm, President, of the Imperial Office of Public Health, Berlin.
- Campbell, Dr., Durban.
- *Chittenden, Prof., Yale University, New Haven, Conn., U.S.A.
- *Clarke, Dr., Bulawayo.
- *Clemow, Dr., Constantinople.
- Currie, Dr., Pietermaritzburg.
- *Curtis, Dr., London.
- *Cushny, Prof., London.
- *Douglas, Capt. H. E. M., V.C., D.S.O., R.A.M.C., Simla, India.
- *Dunbar, Sir William, Bart., Registrar-General, London.
- *Dunlop, Dr., Edinburgh.
- Dunstan, Prof., F.R.S., Imperial Institute, London.
- *Ewald, Prof. A., Berlin.
- *Ellis, H. M., Director-General of the Navy, London.
- *Evatt, Surgeon-General G. J. H., C.B., India Office.
- *Franks, Sir Kendal, C.B., Johannesburg, South Africa.
- Frazer, Sir Thos. R., F.R.S.
- Gamgee, Prof., F.R.S., Montreux.
- *Gregory, Dr., Colonial Office, Cape Town.
- *Hann, Prof. J., Vienna.
- Hardy, W. B., F.R.S., Cambridge.
- *Hay, Prof. Matthew, Aberdeen.
- Herbertson, Prof., Oxford.
- *Herdman, Dr. Ronald, Filabusi, near Bulawayo.
- *Hill, Dr. Leonard, F.R.S., London.
- *Hyslop, Dr., Pietermaritzburg.
- Keltie, Dr. J. Scott, F.R.G.S., London.
- *Keogh, Surgeon-General Sir A., K.C.B., M.D., War Office, London.
- *Kerp, Prof., of the Imperial Office of Public Health, Berlin.
- *King, Col., Sanitary Commissioner, Madras.
- Kronecker, Prof., Berne, Switzerland.
- *Langaard, Prof., Berlin.
- Lankester, Prof. E. Ray, F.R.S., London.
- Latham, Baldwin, M.Inst.C.E., London.
- *Leslie, Lieut.-Col. J. T. W., I.M.S., Simla, India.
- *Liebreich, Prof., Berlin.
- Liversidge, Prof., Sydney, N.S.W.
- MacAlister, Dr. Donald, Cambridge.
- *McCulloch, Major, R.A.M.C., Malta.
- *McGregor, Sir William, Governor, Newfoundland.
- McKendrick, Prof. J. G., F.R.S., Glasgow.
- *Mackenzie, Dr. Leslie, Edinburgh.
- *Manson, Sir Patrick, K.C.M.G., F.R.S., London.
- *Meek, Lieut.-Col. I., R.A.M.C., Poona, India.
- *Melville, Lieut.-Col., M.B.
- Mill, Dr. H. R., British Rainfall Organisation, London.
- *Mitchell, Sir A., K.C.B.
- *Mitchell, Dr. J. A., Colonial Office, Cape Town.
- *Mitchell, Dr. Weir, Philadelphia.
- *Moffat, Dr., C.M.G., Uganda.
- *Moore, Sir John, Dublin.
- *Morgan, Major J. C., R.A.M.C., United Provinces, India.
- *Mosso, Prof. Angelo, Turin, Italy

- *Murison, Dr., Public Health Department, Durban, Natal, South Africa.
Murray, Dr. C. F. K., Cape Colony.
- *Nuttall, Dr., Cambridge.
Oliver, Prof., Newcastle.
- *Osler, Dr. T. H., Cape Colony.
Osler, Prof. W., F.R.S., Oxford.
- *O'Sullivan, Lieut.-Col. D., R.A.M.C., Punjab, India.
Pawlow, Prof., St. Petersburg.
- *Pearce, Capt. C. R., I.M.S., Upper Burmah, India.
- *Pembrey, Dr., London.
- *Phillips, Dr. L. P., Cairo, Egypt.
- *Pinching, Sir Horace, Cairo.
- *Porter, Dr., Johannesburg.
- *Raymond, Major C., R.A.M.C., Nilgiri Hills, India.
- *Reymond, Prof. René du Bois, Berlin.
- *Rochfort-Brown, Dr.
- *Rogers, Capt. Leonard, Calcutta.
- *Rost, Dr. E., of the Imperial Office of Public Health, Berlin.
Ruffer, Dr., C.M.G., Ramleh, Egypt.
- *Salmond, Dr., Ladysmith.
- *Sanders, Dr., Pretoria.
- *Scott, Major B. H., R.A.M.C., Punjab, India.
Shaw, Dr. W. N., F.R.S., London.
- *Simpson, Lieut.-Col. R. J. S., M.B., London.
- *Strangeways, Dr., Cambridge.
- *Tatham, Dr. J. W. F., General Register Office, London.
- *Theiler, Dr., Pretoria.
- *Thiselton-Dyer, Sir William, K.C.M.G., F.R.S., Gloucester.
- *Tropical Schools of Medicine (London and Liverpool), Heads of.
- *Turner, Dr., Pretoria.
- *Usmar, Dr. G. H., Bloemfontein.
Wager, Harold, F.R.S., Leeds.
- *Walker, G. Thos., F.R.S., Simla, India.
- *Ward, Dr., Bloemfontein.
- *Watkins, Dr., Kimberley.
Weber, Dr., Berlin.
- *Weber, Dr. Parkes, London.
- *Welsh, Fleet-Surgeon.
- *Will, Major, R.A.M.C., British East Africa.
- *Woeikoff, Prof., St. Petersburg.
Woodhead, Prof. Sims, Cambridge.
- *Woodhouse, Lieut.-Col. T. P., R.A.M.C., Punjab, India.
- *Wright, Dr. A. E., London.
- *Wutzdorff, Dr., of the Imperial Office of Public Health, Berlin.
- *Yule, Dr. Pratt, Bloemfontein.
- *Zuntz, Prof., Berlin.

At the meeting of Section I (Physiology) on August 16, 1905, the resolution was passed which defined the scope of the above Committee as being, 'To make further research and inquiries' into the effect of climate upon health and disease.

This resolution was considered at a subsequent meeting of the Sectional Committee. The Sectional Committee regarded the subject as so important that they willingly sent forward the resolution to the Committee of Recommendations. Although the duties of the Committee promised to be very laborious, the Sectional Committee felt justified in asking for only a small grant of money (20*l.*) for the year 1905-6. This grant was to be spent on preliminary inquiries, for the purpose of finding out whether the necessary data were obtainable, and whether in the opinion of scientists useful researches could be carried on.

The General Committee appointed the present Committee, and placed 20*l.* at their disposal.

The Committee have confined their work to the two points which have been mentioned.

I. The Collection of Data.—In these matters the Committee must tender their thanks to the War Office, which, through the agency of Lieut.-Colonel Simpson, R.A.M.C., has placed a great mass of data at their disposal.

A suitable list of diseases has been drawn up. It is proposed to circulate this, with suggestions as to the points to be considered in preparing local and district monographs on climate and disease.

II. Experimental Researches.—The following experimenters have undertaken to be responsible for such researches as may seem expedient in the subjects affixed to their names :—

Prof. Kronecker, Hallerianum, Berne, Switzerland	<i>Lowered Pressure.</i>
Dr. Leonard Hill, London	<i>Raised Pressure.</i>
Dr. Pembrey, London	<i>Temperature.</i>
Prof. Bohr, Copenhagen	} <i>External Respiration.</i>
Prof. Zuntz, Berlin	
Dr. J. Barcroft, Cambridge	<i>Internal Respiration.</i>
Prof. Gamgee, F.R.S., Montreux	<i>Light.</i>
Prof. Woeikoff, St. Petersburg	} <i>Electrical Conditions.</i>
Prof. T. Hann, Vienna	
W. B. Hardy, F.R.S.	<i>Radio-activity.</i>
Prof. Benedict, Middletown, Conn., U.S.A.	} <i>Diet in different Climates.</i>
Prof. Chittenden, Yale University, New Haven, Conn., U.S.A.	
Dr. Liversidge, Sydney	
Dr. Porter, Johannesburg	
Prof. Pawlow, St. Petersburg	

III. Procedure.—The Committee suggest that this should be carried on in three ways :—

(a) The preparation of a bibliography, and, if possible, the making of a collection of the existing monographs and papers dealing with the relationship of climate to health and disease.

(b) By the preparation of a list of suggestions as to the chief points to be dealt with in local or district monographs on the relation of climate to health and disease.

(c) To consider the best means of discussing and supplementing existing data as to the relation of the wider geographical distribution of climates and of diseases.

The Committee are confident of the great importance of carrying on this work, and in view of the inquiries which they have made are ready to proceed with it at once.

Obviously the work is very great, and it would be useless to attempt to carry it out on a restricted scale. The Committee ask for a grant of 100*l.* for the ensuing year and for power to confer with other societies or Governmental departments, with the object of obtaining the funds necessary for its work over a course of years.

The 'Metabolic Balance Sheet' of the Individual Tissues.—Report of the Committee, consisting of Professor F. GOTCH (Chairman), Mr. J. BARCROFT (Secretary), Sir MICHAEL FOSTER, and Professor E. H. STARLING. (Drawn up by Dr. F. G. HOPKINS and the Secretary.)

DURING this year 1905-6 the work carried on under the auspices of the Committee has concerned itself with the investigation of three organs—striated muscle, the heart, and the kidney. In addition, preliminary investigations have been made into the amount of blood flowing through others, such as the intestines and the liver.

I. Skeletal muscle has been studied in the frog by W. M. Fletcher and F. G. Hopkins.

This research was undertaken primarily with the intention of further

studying the effect of anaërobic and aërobic conditions respectively on the survival life of muscle. Preliminary results showed that as certain errors were present in estimations of lactic acid, made by earlier observers, the more fundamental experiments had to be repeated. These errors are due to the fact that the preliminary treatment of the muscle produces so much more effect upon the content of lactic acid than has been suspected. Chopping up the muscles may by itself increase the amount of acid very largely, and when intact muscles are placed under alcohol the surface stimulus involved may increase it tenfold. Such errors being eliminated, the following new data have been obtained. The surviving muscle, containing lactic acid due to fatigue, has the power of getting rid of this acid during the recovery of activity which occurs on exposure to an atmosphere of pure oxygen. The rate of this disappearance of acid and the effect of various factors upon it have been studied. The removal depends upon the integrity of the architecture of the muscle fibre. That the removal is due to simple oxidation is not yet certain.

The curve of lactic-acid production in resting muscle has been fully studied, and the results, together with the proof that under certain conditions much larger quantities of acid can be produced than previous experimentation had suggested, indicate that the metabolite either arises from a precursor present in much larger quantity than the pre-existing carbohydrate or (an important alternative) the muscle during recovery from fatigue, &c., synthesises the lactic acid into a complex which may again break down. An endeavour to discriminate between these possibilities will form the basis for future work.

Some preliminary experiments have been performed by Barcroft, Mottram, Stansfeld, and Miss Tweedie on the amount of oxygen used per gramme of skeletal muscle. These experiments yielded a value much lower than what has been observed in many other organs.

An example may be given. In a dog (weight 17 kilos.) the muscles of the right-hand leg weighed 2,980 grammes. The blood-flow through the limb was 150 c.c. per minute. Each 100 c.c. of blood gained 9.2 c.c. of CO_2 , and lost 9.1 c.c. of O_2 . The actual amount of CO_2 gained by the blood and oxygen lost per gramme of muscle per minute was therefore $\text{CO}_2 = .0046$ $\text{O}_2 = .00455$ c.c. This muscle was at rest in the sense that the lumbar and sacral regions of the cord were destroyed. The anaesthesia (A.C.E.) was light.

II. The researches already reported (see 1905 report) upon the mammalian kidney have been extended to that organ in the frog. The chief results which have been obtained are as follows:—

(1) When the frog's kidney is perfused through the renal portal system with oxygenated or aërated saline solution the amount of oxygen used up is markedly less than would be used by the same weight of mammalian kidney.

(2) Under these circumstances there is an increase in the oxygen consumption when the perfusing solution contains caffeine (two experiments), urea 0.1 per cent. (one experiment), sodium sulphate (three experiments); whilst it was greatly reduced by 4 per cent. urea (one experiment) and abolished by 5 per cent. urea (one experiment).

(3) When the same kidney is perfused at different times through the aorta, and through the renal portal system, there is a greater consumption of oxygen in the former case than in the latter (double to treble in four experiments).

(4) The above holds good for kidneys without drugs (two experiments), and for kidneys perfused with 0·2 per cent. sodium sulphate in saline (two experiments). The experiment which has given the most marked result was as follows :—

				Oxygen Consumed per Minute.
Perfused with Normal Saline through Aorta	.	.	.	0·0025 c.c.
" " " " Renal Portal	.	.	.	0·0008 c.c.
" " " " + 0·1 Na ₂ SO ₄ "	.	.	.	0·0018 c.c.
" " " " " through Aorta	.	.	.	0·0049 c.c.

In the last case only was there diuresis. Subsequent injection through the inf. vena cava showed that the kidneys only were contributing to the fluid collected for analysis.

III. *The Heart*.—It has been found possible to perfuse the heart with undiluted blood by the method devised by Heymans—namely, to lead blood from the carotid artery of a large dog into the aorta of a small dog or puppy, to allow it to go through the coronary system of this animal, and to lead it back from the pulmonary artery to the jugular vein of the large dog. The technique of Heymans has been improved for blood-gas purposes by rendering the blood non-coagulable by the injection of hirudin (see 1905 report).

The gaseous metabolism of the heart is reduced by influences which diminish the rate or amplitude of the heart's contraction or the tonus of its muscle, *e.g.*, pilocarpine, KCl, vagus stimulation; whilst its gaseous metabolism is increased by drugs which have a contrary effect, adrenalin, atropine after pilocarpine, BaCl₂ after KCl.

The rate of blood-flow through the coronary system varies, other things being equal, with the amount of CO₂ produced by the heart.

IV. *Apparatus* has been devised for estimating the quantity of oxygen dissolved in 10 c.c. of salt solution. The following figures give an idea of its accuracy :—

—	Apparatus.			Winkler.	Bohr & Bock.
Percentage of Oxygen in water saturated with air at 15° C.	·71	·72	·71	·72	·75
Percentage of Oxygen in water saturated with air at 17° C.	·68	·70		·69	·70
Nitrogen in water saturated with air at 17° C.	1·37	1·41	1·39	1·28	1·36
	1·41	1·44	1·34		

The Committee ask for a further grant of 45l., the grant of last year having all been expended.

The State of Solution of Proteids.—Fourth Report of the Committee, consisting of Professor HALLIBURTON (Chairman), Professor WAYMOUTH REID (Secretary), and Professor SCHÄFER. (Drawn up by the Secretary.)

SINCE the experiments of the past session are not yet completed, a full report must be delayed till a future occasion.

The main object of the experiments has been to attempt to construct

artificially some sort of proteid membrane associated with bodies belonging to the lipid class which would imitate, as far as possible, in its properties the pellicle on the surface of the mammalian blood corpuscle.

The preparation of the lipid substances in quantity and in a fair state of purity has naturally occupied much time. The lecithin, cephalin, and cerebrin were separated from sheep's brains, the method of Waldemar Koch being to a large extent followed.

After boiling out thoroughly with acetone for many hours, to remove water and extractives, the acetone was driven off by heat and the residue repeatedly extracted with large volumes of pure ether.

This extract, holding the lecithin and cephalin, was allowed to evaporate during a month slowly to about a quarter of its original volume.

Meanwhile the ether-extracted brain matter was boiled out many times with alcohol and the crude cerebrin separated by cooling to 0° C. This product was then repeatedly crystallised from hot glacial acetic acid and dried *in vacuo* over lime. The resulting substance had a melting-point of 188° C., taken in a bath of sulphuric acid.

From the ethereal extract holding the cephalin and lecithin the former was separated by adding excess of absolute alcohol and the filtrate set aside for subsequent removal of lecithin.

The crude cephalin was extracted many times with boiling alcohol dissolved in ether and precipitated with acetone.

It was finally again dissolved in ether, allowed to stand, the ether evaporated, crystallisation twice carried out from hot acetic ether, and dried *in vacuo* over sulphuric acid.

The crude lecithin was recovered from the solution in alcohol and ether above mentioned by evaporation of the solvents, again dissolved in pure ether, and freed of cholesterine by precipitation of the solution with acetone. The precipitated lecithin was then taken up in cold alcohol, filtered, evaporated, and finally three times crystallised from hot acetic ether and dried *in vacuo* over sulphuric acid.

The oleic-acid ester of cholesterine was also prepared by heating pure cholesterine and oleic acid together at 200° C. for several hours and repeatedly crystallising the product from hot alcohol till a melting-point of 42° C. was reached.

With the material so prepared a series of experiments is in hand in which various membranes have been constructed and tested for permeability to salts. The following membranes are some of those so far put to the test:—

(a) Lecithin emulsion (obtained by pouring ethereal solution into water) and 10 per cent. gelatine supported in the pores of peritoneal membrane.

(b) Peritoneal membranes soaked in blood serum and treated with ethereal solution of lecithin.

(c) The same as (b), but using white of egg in place of blood serum.

(d) Celloidin lecithin membranes.

(e) Peritoneal membrane with cholesteryl oleate in the pores.

(f) Same as (e), but using cephalin.

It has been found that over long periods none of these membranes are impermeable to either sodic or potassic chloride, but the rate of initial osmosis is by no means the same in the different cases.

Intercurrent with the above experiments, the old experiment of Norris, proving that the shape of the red blood corpuscle is that of a 'myelin form,' has been repeated with the pure lipid substances to hand in the laboratory. By making 'spreads' of solutions in alcohol or ether on slides, treating with water, and examining microscopically, or by pouring solutions into water, shaking, and centrifugalising, all varieties of myelin forms were formed from pure lecithin, commercial lecithin, cholesteryl oleate, kephalin, cerebrin, and mixtures of these substances.

The biconcave-disc and the cup forms of red blood corpuscles are best got by using a mixture of 2 per cent. lecithin and 1 per cent. cholesteryl oleate in alcohol, either poured into water or dried on a slide and treated with water. These 'artificial corpuscles' are, especially after staining, easily confounded with real corpuscles similarly treated.

Norris attributed rouleaux formation to the lipid pellicle of the red corpuscles, but it must be stated that the 'artificial corpuscles' prepared from pure lecithin and cholesteryl oleate and mounted in water show no tendency to stick together. One can watch them approach each other, touch, and swim apart.

Apparently the cholesteryl oleate, or some such body, is necessary for the formation of a good imitation of the natural shape.

Lecithin alone, cholesteryl oleate alone, or lecithin and crystalline cholesterol give emulsions consisting of tubular myelin forms in the first case, or irregular granular forms in the latter two.

The addition of cerebrin to the lecithin and cholesteryl oleate interferes with the formation of good imitations of the shape of a red corpuscle.

Peat Moss Deposits.—Interim Report of the Committee, consisting of Professor R. J. HARVEY GIBSON (Chairman), Professor R. H. YAPP (Secretary), Professor J. R. GREEN, and Mr. CLEMENT REID, appointed to investigate the Peat Moss Deposits in the Cross Fell, Caithness, and Isle of Man Districts.

The Committee have received the following Report from Mr. Francis J. Lewis :—

This investigation has so far been confined to the Cross Fell District. Owing to the complications met with in the peat strata much section cutting has been necessary. These complications are due to two causes : (a) the variation in altitude from 2,850 to 1,400 feet ; (b) to widespread beds of silt and clay intercalated in the peat.

The silt has been brought down from Cross Fell lying at about 2,500 feet at certain intervals and spread broadcast over the lower ground. This has introduced local changes in the flora, due to ecological factors, and has made the correlation of the various beds extremely difficult. The lower ground, lying at 1,800 to 1,500 feet, has still to be examined, and it is hoped that here better evidence will be obtained as to the positions of the lower and upper forest beds.

The chief point of interest up to the present time is the discovery of a well-marked arctic-plant bed lying at the base of the peat. A silty

clay occurs in some places on the banks of and partly under the River Tees at about 2,000 feet, crowded with well-preserved leaves of *Salix reticulata* and *S. Arbuscula*. The stems and frequently the leaves of these plants are abundant at the base of the peat over the whole of this district.

The complete correlation of these beds with similar ones described from various districts in the Highlands¹ is not possible until the peat at lower levels has been examined and the position of either one or both of the forest beds determined.

For this purpose I request permission to retain the balance of the grant, 7*l.* 5*s.* 7*d.*, now in my hands, so that the Caithness and Cross Fell Districts should be finished during the present year.

Research on South African Cycads.—Interim Report of the Committee, consisting of Mr. A. C. SEWARD (Chairman), Mr. R. P. GREGORY (Secretary), Dr. D. H. SCOTT, and Dr. W. H. LANG.

A. Professor Pearson has made two journeys into the Cycad region, viz. :—

1. September 20–27, 1905. To Queenstown, the centre of the area of a species of *Encephalartos* known as *E. cycadifolius*.

2. April 26 to May 7, 1906. To East London and the surrounding country. Here are found *Encephalartos Altensteinii*, '*Encephalartos villosus*,' and a *Stangeria*. He also paid a second visit to *E. cycadifolius* at Queenstown on his return.

The biology and conditions of life of these species have also been studied, and a small paper on the subject is communicated to the Association at the present meeting. Herbarium specimens have also been collected with a view to a systematic revision of the group, and material has been fixed for reasearch on their life-histories.

B. Professor Pearson has also been able to interest in these investigations certain forest officers and private persons residing in the cycad districts, from whom he has been constantly receiving cones and herbarium material.

C. Professor Pearson has almost concluded an investigation into the development of the microspore of *Stangeria*, a stage which Dr. Lang's material did not enable him to follow out. The preparations are all made and some of the figures drawn. The author is disappointed that he can only communicate a preliminary note on the subject to this meeting of the Association, as unforeseen circumstances have prevented him from completing the work in time.

D. A large number of preparations of various stages of the archegonium and of the germinating pollen of *Encephalartos Altensteinii* has also been made : a large amount of fixed material of this and other species is awaiting

¹ Francis J. Lewis, 'The Plant Remains in the Scottish Peat Mosses. Part I.: The Scottish Southern Uplands,' *Trans. Royal Soc. Edin.*, vol. xli., No. 28, 1905, 24 pp., 7 plates and diagrams. 'The Plant Remains in the Scottish Peat Mosses. Part II.: The Scottish Highlands,' *Trans. Royal Soc. Edin.*, June 18, 1906, 30 pp., 5 plates and diagrams.

examination. The ciliated spermatozoid and the dividing nucleus of the central cell prior to the formation of the canal-cell nucleus have been found, while certain peculiarities in the behaviour of the oosphere nucleus previous to fertilisation require further investigation. It is not intended to publish these results at present.

The herbarium material which is being accumulated is held at the disposal of Sir W. T. Thiselton-Dyer in the hope that he may be able to use it in the preparation of a monograph of living cycads or, failing this, it may be used by the author of the 'Cycadaceæ' for the *Flora Capensis*.

Of the sum of 50*l.* granted by the British Association in aid of these investigations only about 15*l.* has been spent. That so small a proportion has been used is due to the following facts :—

1. Professor Pearson was compelled to go to England during the last Long Vacation (November 1905 to March 1906), and was therefore unable to make a contemplated journey to the Transkei.

2. His visit to Queenstown in September 1905 was made on a free railway ticket, which was obtained in consideration of his being a local secretary of Section K at the Johannesburg meeting.

3. Since the grant was made he has been able to arrange that all cycad material addressed to him should be conveyed free of charge by rail or post from any part of South Africa. This has resulted in a saving of at least 10*l.*

4. The extraordinary hospitality of the colonist and his reluctance to allow the payment by a visitor of legitimate expenses.

The Structure of Fossil Plants.—*Second Interim Report of the Committee, consisting of Dr. D. H. SCOTT (Chairman), Professor F. W. OLIVER (Secretary), Messrs. E. NEWELL ARBER and A. C. SEWARD, and Professor F. E. WEISS.*

MR. ARBER reports that he has obtained through the grant specimens of *Sigillaria*, referable to *Sigillaria scutellata*, Brongn., or some closely allied species, showing both external characters and anatomical structure. A full account of these specimens, and of those previously obtained, is in preparation.

Professor Weiss has obtained sections of a new type of *Stigmaria*, which is under investigation, together with the specimens acquired last year.

Professor F. W. Oliver's description of the seed *Physostoma elegans*, in part based on the slides obtained from this source last year, is in a forward state, and may, it is hoped, appear during the autumn. The specimens of *Conostoma oblonga* obtained this year are still under investigation.

The Committee apply for the renewal of the undrawn grant of 20*l.*, as new specimens bearing on the various investigations in progress are constantly coming to light.

Botanical Photographs.—*Report of the Committee, consisting of Professor L. C. MIALL (Chairman), Professor F. E. WEISS (Secretary), Mr. FRANCIS DARWIN, Mr. W. G. SMITH, and Mr. A. G. TANSLEY, for the Registration of Negatives of Photographs of Botanical Interest. (Drawn up by the Secretary.)*

DURING the past year sixty-two photographs have been added to the collection, including a series of twenty-two photographs illustrating the vegetation of Teneriffe made by Mr. Hugh Richardson of York, a further set of photographs of Irish plants by Mr. R. Welch of Belfast, and a series of photographs of alpine plants by Mr. G. K. Ballance. The Secretary attended a meeting of the Central Committee for the Survey and Study of British Vegetation, at which a proposal was made that the photographs of British vegetation which are of ecological value should be placed in the custody of the Central Committee for the Survey of British Vegetation, and should be housed at University College, London. This proposal requires ratification by the Committee of Section K.

No portion of the grant of 3*l.* has been expended.

The Conditions of Health essential to the carrying on of the Work of Instruction in Schools.—*Report of the Committee, consisting of Professor SHERRINGTON (Chairman), Mr. E. WHITE WALLIS (Secretary), Sir EDWARD BRABROOK, Dr. C. W. KIMMINS, Professor L. C. MIALL, and Miss MAITLAND.*

During the year the Committee have set out several matters for investigation affecting the health and physical well-being of children in schools. Sub-Committees have been appointed to investigate these several matters, but some of the investigations are not yet complete. They submit, however, for consideration of the Section this year reports upon hearing and teeth of children, and upon children's playtime and leisure.

The Committee had in co-operation with them in their investigations and deliberations the valuable assistance of Miss Findlay, Mrs. Gomme, Mrs. White Wallis, Mrs. Kimmins, Miss Ravenhill, Miss Ross, Dr. Friedberger, Dr. Ballance, Mr. Sydney Spokes, Professor H. R. Kenwood, and Dr. Shelley.

Children's Hearing.

The ear being the chief channel of instruction, it is unnecessary to dilate upon the importance of taking steps to ensure that the hearing of schoolchildren is satisfactory.

Various methods have been adopted for testing the hearing of children, and for this reason it is not always easy to compare the results of different workers. In our opinion it is desirable to adopt some standard method, one which is as simple as possible and one which is not deceptive in its results. We are of opinion that there are drawbacks attaching to the

various methods hitherto adopted, and if our Committee is reappointed we are prepared to undertake experiments with the view of arriving at a suitable standard method.

We have, however, satisfied ourselves of the fact that disease of the ear is very prevalent among schoolchildren. The statistical returns which have been compiled in this and other countries (notably in Germany, Sweden, Switzerland, and America) show that from 12 to 20 per cent. of schoolchildren may be defective in their hearing.

Aural disease, even when slight, affects not only the child's health, but its capacity for earning its living in the future. In this connection the following rules may be laid down :—

(a) That any child recently admitted to a school who breathes through the mouth, or whose hearing is defective to the extent that he or she is unable to hear without effort the words spoken by the teacher, should be examined. It has been repeatedly observed that children whose hearing is defective have been thought inattentive, careless, and lazy, and blamed as such, before it was discovered that they experienced difficulty in hearing.

(b) After an attack from an infectious disease, even when there are no apparent signs of the hearing having become impaired, a child's ears, nose, and throat should be thoroughly examined. The reasons why the above action is recommended are the following :—

It is a well-known fact that a diseased condition of the nose or throat, both of which are very prevalent, is one of the most frequent causes of diseases of the middle ear, and it is, therefore, very desirable that the diseased condition of the nose or throat be taken in hand in good time.

It is another well-established fact that acute infectious diseases, such as measles, scarlet-fever, diphtheria, influenza, pneumonia, and others, are frequently followed by aural trouble, which, so long as it affects only *one* ear, does not appear to be necessarily attended by any very marked degree of deafness. Experience has likewise shown that acute infectious illnesses not infrequently lead to catarrh of the nose and throat, and to chronic swellings and growths of the adenoid tissues, whereby the hearing is permanently impaired.

The teacher should first write to or interview the parents of any child whose hearing is impaired, and insist upon serious endeavours being made to have the trouble attended to forthwith. For aural mischief of recent date can be cured much more easily, more rapidly, and more completely and permanently than when it has become chronic.

These suggestions as regards prophylactic treatment could be carried out in a satisfactory manner only in the event of arrangements being made whereby the poorer schoolchildren could be examined and treated ; and the most satisfactory arrangement would be one by which the ears of all scholars were examined twice yearly by ear specialists.

Any child whose hearing has become incurably impaired should, if possible, take part in the instruction given to children whose hearing is normal, inasmuch as if a place be assigned to it as near as possible to the teacher it is often capable of following the lessons in a satisfactory manner. It must not be left out of account in this connection that children with defective hearing are much more easily exhausted by their lessons than children whose hearing is normal. Consequently, their lessons should be limited to the most essential teaching.

Children whose hearing is incurably impaired, and who are unable to take part (as suggested) in the same lessons as children whose hearing is sound, should be taught separately in a class set aside for children with defective hearing, or must be taught singly.

Teachers should always bear in mind that children whose hearing is defective invariably understand best of all the middle sounds, and clear, slow, sharply accentuated speech.

Children who are really deaf should be sent to special schools, which local educational committees are empowered to establish, or to institutions for the deaf and dumb.

The cost entailed by any scheme which would make the provisions above indicated would, in our opinion, be more than repaid by the resulting benefits accruing to the scholar and the citizen.

Children's Teeth.

The importance of sound teeth has reference, not only to efficient mastication and preparation of food for the alimentary canal, but recent observations go to show that some grave constitutional conditions have also their origin in a dirty, foul mouth with broken-down teeth. Carefully collected statistics show that a large proportion of schoolchildren in elementary schools have a condition of teeth which will not effectively deal with food with which they are supplied.

In regard to the prevalence of dental disease, it must be admitted that the most common departure from a normal healthy condition of the human body is found in the decay of teeth. Although it was generally known that children's mouths afforded evidence of much decay, it is only within the last few years that the actual extent has been demonstrated. The British Dental Association made a collective investigation as to the condition of the teeth of children in poor-law schools, workhouses, and reformatories. 10,500 English and Scotch boys and girls of an average age of twelve years were examined. These children had 37,000 unsound teeth. There were 18,000 decayed temporary teeth, more than half of which should have been 'stopped.' There were 19,000 decayed permanent teeth, 13,000 of which should have been saved, and 6,000 required extraction. Fourteen per cent. only of these children had teeth free from decay. With respect to the cause of such prevalence, neglect must stand first. Deterioration of teeth is intimately connected with a variety of intricate causes affecting the general health of the nation, but there seems to be some divergence of opinion as to what the chief factors are which lead to early decay of teeth. All are agreed that the great cause of decay of teeth is improper or insufficient nutrition during infancy and childhood, and that the development and growth of the teeth suffer in proportion to the general malnutrition of the body resulting from defective feeding, which may be on account of ignorance on the part of the mothers, food adulteration, or actual inability of the parents to provide proper food. There can be little doubt that dietetic errors, poverty with insufficient food, inherited disease, and the unhealthy environment which poverty usually entails—*e.g.*, defective housing, overcrowding, and insanitary surroundings—must all be factors powerfully influencing the growth of the body, and actively antagonistic to healthy physical development of all its tissues and organs. But malnutrition plays but a very small part in the production of dental caries,

as compared with the common use of articles of food which readily undergo acid fermentation, and it is neglect to keep the mouth clean that is chiefly responsible for the decay of teeth.

As to suggestions for the prevention of decay and the preservation of teeth, no doubt prophylaxis is the ideal object to aim at, but in the meantime it must be the duty of those responsible for the bringing up of children to deal with conditions now existing. In England the children of the poorest—that is, those who are actually paupers—are in many ways better off than those next above them in the social scale. The Poor-law Guardians, who stand *in loco parentis*, appear on the whole to recognise their responsibilities to the children in regard to teeth; for many Boards of Guardians, and especially those in the London districts, have, with the sanction of the Local Government Board, appointed dental surgeons during the last decade, and much good has already resulted. The systematic examination affords an opportunity for arranging to save all teeth which can be treated, very many of them teeth of the first or 'milk' dentition; it also discloses the shocking condition existing in a large number of such mouths, due to broken-down, necrosed and septic remains, which otherwise escape notice unless the child has an attack of acute pain.

The children in our public elementary schools are practically left without conservative treatment, and so are in a much more neglected state than the poor-law children. Some of them, no doubt, obtain hospital treatment, but probably only in the form of extraction.

The Committee supports as emphatically as possible the recommendations of the Admiralty and War Office Inter-Departmental Committee, endorsed by the Inter-Departmental Committee on Physical Deterioration, viz. :—

'1. That the teaching of the elements of hygiene should be made compulsory in schools, and in this teaching the care of the teeth should receive attention.

'2. That daily cleansing of the teeth should be enforced by parents and teachers.

'3. That systematic examination of the teeth of children by competent dentists employed by school authorities should be practised where possible, to prevent caries extending, to stop carious teeth, and to remedy defects of the teeth.'

The Committee further emphasise the great importance of making more widely known the serious constitutional results arising from decayed teeth.

Children's Playtime and Leisure.

Your Sub-Committee have pleasure in reporting that they have made inquiries of America, Germany, France, and more exhaustively of England, concerning the question of the amount of time left to children for play and leisure during the school period of their life.

The result of these inquiries enables your Sub-Committee to put the following conclusions before you, and they have also tabulated the information in correlated time-tables, which they append.

In the case of America and Germany the information at their disposal is not enough to be of much value.

In France, they find that in two lycées the average leisure of an

élève de six is twenty hours per week of six days—that is, about three hours and a half of leisure during the day; while the *élève de rhétorique* has only about twelve hours per week, or two hours a day.

In French elementary schools the leisure of the child amounts to seventy-five minutes during the school-time of the week. That is, fifteen minutes a day, in two breaks, besides the dinner hour, during the school day of seven and a half hours, for five days in the week. Dr. Mathieu says that, besides having tasks to do at home, the children are also sometimes obliged to work two or three hours outside the school. Their leisure, therefore, might amount to a whole holiday on Thursday, and on each school-day two breaks amounting to fifteen minutes, besides a possible hour or two in the evening. This is always supposing such leisure is not encroached upon by the adult.

From England it is found that in boys' public schools games (more or less compulsory) and leisure occupy from twenty-six to twenty-eight hours per week of six days, being equal to four and a half hours a day.

In girls' public schools thirty-five hours per week of six days, or about six hours a day, seems a fair average of the time allotted to games and leisure. But the extremes vary widely; for instance, one foundation school appears to have forty-two hours a week, or seven hours a day, while one of the college schools has only twenty-seven hours a week, or *four and a half hours* a day.

It should be noted that the newly opened St. Paul's School for girls gives an interval of five minutes between each pair of lessons, except where the luncheon interval of fifteen to twenty minutes occurs. Pupils under fifteen have no home work.

Also, that the King Alfred Schools Society's mixed public school gives an interval of five minutes after each lesson, and has no home work at all (unless specially desired by the parents).

In elementary schools in England the leisure of the child during the school hours of the week amounts to an hour and forty minutes—that is, two breaks of ten minutes each a day during the five and a half hours' daily school work.

In preparing the correlated time-tables the Committee has found it impossible to take into consideration the teaching and practice of instrumental music. In almost all cases where music is studied, the time so spent will be deducted from that allotted to leisure, making it less than it appears in the report.

It appears that in matters political and social it is the tendency to shorten the hours of work, because by so doing it is found possible to put more concentrated effort into what is being done and more effective results are obtained.

The same is true of school education; but in order to obtain this concentrated effort from children it is absolutely essential that they should have frequent pauses between lessons, as well as a large amount of leisure during each day.

It is satisfactory to find that the new St. Paul's School for girls is adopting these more hygienic methods, and that the King Alfred Schools Society's demonstration school in Hampstead has had them in practice for several years. The results appear to be in every way satisfactory, and your Committee, after considering the information they have before them

are of opinion that for the growth and maintenance of mental health a system should be adopted of—

1. Short school hours of vigorous work, guided or independent, broken by frequent intervals of relaxation.

2. That teachers be encouraged to secure the co-operation of parents in affording the children opportunities to develop their own individuality in home life.

3. That no home lessons be set by the school for younger children.

4. That the curriculum of elementary schools should include a scheme for organised play.

5. That organised play should consist of such games as will develop the physical and mental powers of the child in grace of movement, voice culture and imagination, and will continue in the home the lessons unconsciously taught under this system.

The Committee desire to be reappointed and ask for a grant of 5*l.*

Studies most suitable for Elementary Schools.—Report of the Committee, consisting of Sir PHILIP MAGNUS (Chairman), Mr. W. MAYHOWE HELLER (Secretary), Sir W. DE W. ABNEY, Mr. R. H. ADIE, Professor H. E. ARMSTRONG, Miss A. J. COOPER, Miss L. J. CLARKE, Mr. GEORGE FLETCHER, Professor R. A. GREGORY, Principal GRIFFITHS, Mr. A. D. HALL, Dr. A. J. HERBERTSON, Dr. C. W. KIMMINS, Professor J. PERRY, Mrs. W. N. SHAW, Professor A. SMITHELLS, Dr. LLOYD SNAPE, Principal REICHEL, Mr. H. RICHARDSON, Mr. HAROLD WAGER, Miss EDNA WALTER, and Professor W. W. WATTS, appointed to report upon the Course of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.

THE consideration of the courses of experimental, observational, and practical studies most suitable for elementary schools has necessarily directed the attention of the Committee to the general curriculum of such schools, with particular reference to the Government Code. Some re-arrangement of the subjects of instruction would need to be made if room is to be found for practical studies, and if such studies are to become an essential part of the curriculum. The Committee are satisfied that the intellectual and moral training, and, indeed, to some extent the physical training also of boys and girls between the ages of 7 and 14, would be greatly improved if active and constructive work on the part of the children were largely substituted for ordinary class teaching, and if much of the present instruction were made to arise incidentally out of, and to be centred around, such work.

The aim and purpose of elementary instruction for many years was nothing more than the enabling of children to read and write and reckon. If we include in reading not only the art of reading aloud, but the cultivation of a taste for reading and the ability to apply the knowledge so gained to the practical needs of life, and if in teaching a child to write we teach him at the same time to express his ideas intelligibly in written language, and if, further, the child is practically taught the simplest rules of arithmetic, such a training would constitute all that is

most essential in primary education. Gradually, however, the curriculum of elementary schools has been enlarged, and the problem of primary education has been complicated by the multiplication of subjects and by the introduction of many of the faulty methods of teaching which were for many years, and are still to some extent, prevalent in secondary schools. If practical studies, whether experimental or observational, or both, are to dominate the teaching, a fundamental alteration must be made in the methods of instruction, and certain subjects must be omitted from the curriculum, which is already overcrowded. There can be no doubt that, owing largely to the requirements of the Code and to the effect which the receding shadow of 'payment by results' has cast upon our schools, the teaching has become too academic and mechanical, and it is felt that greater attention to practical work, to the encouragement of 'learning by doing,' can alone lift the teaching out of the grooves into which it has fallen.

It is desirable that children from the earliest age should be taught to think. It may be said that thinking is a mental process that can be cultivated only at a later stage in the child's training. But this is not so. No one can have watched a child at play without recognising that, in the adjustment of the end in view to the means at the child's disposal, he is exercising the reasoning faculty. It would seem that it is only in school that the thinking process is allowed to remain unexercised and dormant. In order however that a child may think, he must be actively occupied with the consideration of concrete things. This, as is the case when the child is at play, is essential, and the contrast is very striking between the directed attention of the child when actively engaged in some work that interests him and his listless attitude in the school class-room. During the greater part of the school hours the 'doing' faculty of the child is almost entirely ignored, and the training which he receives fails in consequence to develop along serviceable lines his natural spontaneous activity, and to encourage his ability to initiate and construct. These faults, inherent in our present system of elementary education, would be, it is believed, to a great extent removed if practical studies, involving hand-work and simple experimental methods of acquiring knowledge, were made an essential part of the teaching in every elementary school. At present no obligation exists to provide such practical teaching.

Exercises involving progressive handwork, experimental methods, and subjects of instruction requiring accurate observation may not produce the same manifest and reproducible results as those which occupy so large a part of the present curriculum. But the results would be more lasting and would afford an intellectual training exceeding any that may be obtained from literary studies alone. It is generally acknowledged that much of what is learned in the elementary school is forgotten soon after the child has left school, and a great part of the heavy cost of his education is thus practically wasted. The studies commonly pursued, owing to some extent to faulty methods, fail to fix in the mind the knowledge hastily acquired, and fail also as instruments of sound mental discipline, or as the means of forming permanently useful habits of thought. Much of what is now taught as arithmetic and English is open to this criticism. Time might be found for more practical methods of teaching by throwing overboard a large amount of the instruction given under these heads, and by co-ordinating to a great extent the teaching with the practical exercises which should form the basis of elementary training.

By associating the teaching of arithmetic and English with constructive work, the interest of the child would be stimulated and his education would be more closely directed to the subject of study. Moreover, he would not only acquire habits of accuracy by careful observation and manual exercise, but would learn to use number as an instrument of exact measurement, and, by describing what he had seen and done, to express his ideas in clear and intelligible language. Reform is much needed in the teaching of these two subjects. Too much time is spent in teaching rules and processes which are seldom needed and which are far in advance of other subjects of more immediate value. The ease with which the results of arithmetical work may be tested by teachers, examiners, and inspectors, has had the effect of exaggerating its importance, when pursued beyond its mere elements, and of encouraging practice in the working of complicated exercises of no possible practical value. It is in the teaching of arithmetic that the greatest reform is needed. The exercises should be closely connected with drawing and with measurement, and questions involving money calculations should be definite and concrete and have reference to the cost of materials with which the pupil is already familiar. There is no need for the use of any text-book. The things by which the child is surrounded and the questions arising out of the work with which he is practically engaged afford abundant opportunities of illustrating the simple processes which are all that the child need learn at this stage of his studies.

The ordinary English studies may be similarly modified and curtailed. Transcription, spelling, writing, and dictation should all be included under the head of composition. Grammar, as ordinarily taught, may be regarded as altogether unnecessary and useless. The learning of history should be associated with geography, and although some systematic instruction may be desirable, much of what is most needful may be taught incidentally. The reading lessons should be so chosen as to impart a knowledge of national history and to excite the child's curiosity to know more, and for a certain time a child should be left among books, free to read what he likes, describing afterwards what he has read. Reading aloud should be cultivated, and composition should be taught not by requiring the child to write essays on subjects about which he knows next to nothing, but by describing things he has seen, events in which he has taken part, or work which he has done. By thus associating the teaching of arithmetic and English subjects with practical studies, which keep the child actively occupied—always putting forth energy, instead of passively taking in facts—time would be found for constructive work and careful observation, and the results of elementary education, instead of being, as they now are, too often fleeting and aimless, would create in the child permanent aptitudes for further study and activities which would prove of the utmost value in his subsequent work.

It may be said that in such a scheme of elementary education there would be no uniformity. Possibly not. But uniformity is not in itself an end to be aimed at. The uniformity ideal cramps the initiative of the teacher. There is ground for apprehension that the organisation of secondary education under State control may tend to destroy that variety and diversity of method which has its distinct advantages. The character of the teaching in elementary schools must vary with local requirements and surroundings. This fact is undoubtedly recognised in the Govern-

ment Code. But although the principles underlying the teaching should be very much the same, there might and should be the greatest variety in the subjects to the teaching of which those principles are applied. For this reason it is undesirable to indicate too definitely the exact course of studies most suitable to elementary schools. Much must be left to the judgment and discretion of the head teacher, whose training should enable him to arrange courses of practical study adapted to the requirements of particular schools. Certain general principles, however, may be laid down, and typical courses might be prepared showing the progressive character of the instruction and its connection with such subjects as arithmetic and English, including history, geography, literature, and composition.

The first thing to determine is the kind of practical work most suitable to local requirements and to the ages and conditions of the school-children. The practical work should in all cases begin with Kindergarten exercises, properly arranged, and with observation of common things, of the school surroundings and plant life. Until the higher standards are reached there need be no difference in the training of boys and girls. The Kindergarten exercises should be followed by a course of manual training in the case of boys, and of domestic teaching in the case of girls. For children of either sex there should be a parallel course of simple lessons in experimental science, to be varied in urban and rural districts, and in drawing, to be adapted in the later stages to constructive work in the case of boys, and to needlework in the case of girls.

The course of instruction in constructive work should consist largely, but not exclusively, of exercises in the use of wood-working and metal-working tools. Although wood is undoubtedly the most useful material for manual training, other familiar materials should be employed, and the exercises, which should be as varied as possible, should be such as help in the development of the constructive faculties and embody the representation of an idea. Great importance should always be attached to accuracy and to the maintenance of a high standard of workmanship, both for its moral influence and with a view to the formation of useful habits. This part of the subject has been fully dealt with in various papers by persons who have devoted considerable attention to manual training. It is important, however, to repeat here what was stated in a paper on the subject read at the meeting of the Association at Cambridge in 1904, that the course of instruction should be distinctly progressive, and should be made continuous throughout the standards by means of simple exercises, requiring the use of such tools as may be manipulated by very young children.

Outline courses of instruction in Nature study, in experimental science, and in domestic matters, may with advantage be consulted by the teachers, but official syllabuses should be regarded only as indicating some of the subjects which might be selected for study in elementary schools. Lessons in composition, geography, arithmetic, and drawing, should have close reference to these subjects, leading the child to think for himself, and to desire further knowledge, and to enable him to realise more fully the meaning of the work in which he is engaged.

Useful suggestions as regards elementary science lessons will be found in the syllabus prepared for the Irish National Schools, entitled 'Notes for Teachers in National Schools.'

The teaching of domestic matters to young girls should be of a very

elementary and practical character. The science lessons to be given in connection with the subject should have for their main object the inculcation of habits of accuracy and cleanliness. The importance of exact method, and of using vessels which are scrupulously clean, may best be illustrated by the simplest chemical manipulation, and the school should be furnished with a room—not necessarily a laboratory in the sense in which that term is generally employed—in which easy experiments may be performed by the children themselves. As lessons in cooking cannot be given usefully until the child has acquired some manipulative skill, and has reached the higher standards, it is better that the courses of experimental science should precede the practical teaching of that subject. It is a matter for consideration whether the science lessons should be combined with the teaching of cooking, illustrating as they arise some of its underlying principles, or whether they should run parallel with the instruction or should precede the practical teaching of the subject. Something may be said for each of these plans, but the balance of advantage is in favour of the last, attention being directed to the results of the scientific experiments with which the child would be previously familiar in explanation of cooking processes.

The selection of subjects for the science lessons and the arrangement of experiments to be performed by the children themselves demand much thought on the part of the teacher, and should not be undertaken without careful preparation. They should be such as would find full illustration in the practical teaching, not only of cooking, but of housewifery and general hygiene. The lessons in cooking must be essentially practical. Demonstrations in class will not suffice. This is generally recognised, but it is important that the dishes to be prepared by the pupils should be selected with a view to economy, and should be such as might reasonably be provided in a poor man's home. All waste should be avoided. Nothing should be thrown away, and the child should be shown how to utilise portions of food which are too often regarded as useless. At best, however, only a foundation can be laid in an elementary school for further instruction in evening classes and in secondary schools, but the foundation should be solid and serviceable as far as it goes.

It is generally agreed that work of a practical character cannot be carried on in large classes. The Committee therefore consider that a reduction in the size of the classes is necessary, if effect is to be given to their recommendations.

The teaching of domestic matters to girls should be regarded as the central subject of instruction, around which other subjects should be grouped. It is all important to the happiness of the home and to the healthy rearing of children. It should include needlework, cooking, household management, and the rudimentary principles of hygiene. In all these subjects it is essential that the lessons should be adapted to the ages of the children and the conditions of their home life. Many useful suggestions will be found in the valuable report recently issued by the Board of Education on 'School Training for the Home Duties of Women' in certain foreign countries. In the admirable contribution by Miss Helen E. Matheson on 'Housewifery Instruction in State-supported Schools in Belgium,' the following paragraphs on the teaching of domestic economy demand special consideration: 'The lessons have an essentially practical bearing: inductive methods of teaching are employed, and the teachers are expected to exercise the reasoning power of their pupils.'

The syllabus is not in any way binding; the teachers can modify it according to the particular need of the pupil and according to local conditions, which vary, for instance, in agricultural and in industrial neighbourhoods.

‘As with needlework, indirect application or correlation is adopted as much as possible; reading, writing, arithmetic, botany, hygiene and other lessons are brought into touch with domestic economy.

‘The teachers encourage the girls to practise at home what they learn at school, and to apply principles of order and neatness to their own persons, and also to their younger brothers and sisters. In most well conducted elementary schools the girls, in turn, are expected to keep their own class-room clean and tidy—polish handles, dust, &c.—in addition to the ordinary function of monitress. In rural districts, many primary schools have a garden where the pupils are given practical instruction.’

It is evident that teaching of the kind here indicated can be given only by well-trained teachers. To secure instructors who are competent to make practical studies the essential part of elementary education, the principles underlying the curriculum of training colleges would need revision. It is indeed of the utmost importance that teachers in training should receive a sound literary education. No teacher can be efficient without literary culture. It is equally necessary that the training college should afford adequate instruction in the practice of teaching and in the history and theory of education; but, in addition to these subjects, practical work and the methods of directing it should occupy a much more prominent part in the curriculum than is at present allotted to it.

The study of experimental science, whether physical or biological, must be pursued so far as to enable the student to have a firm grip of his subject, and to be capable of arranging courses of lessons suitable to the requirements of children. The general training should be such as will enable the teacher to correlate the ordinary subjects of school instruction with the practical studies to be developed in the school. This is a branch of pedagogy to which it would seem that very little attention has been so far given. The dominating influence of examinations which teachers are required to pass, the insufficient time devoted to training in practical studies, whether in the laboratory or workshop, are among the causes which prevent training colleges, as at present organised, from affording the kind of education which experience has shown to be necessary to enable teachers to direct and to take part in the practical training of their scholars. It has been well said by an inspector who has had large experience that ‘few teachers on leaving the training college have realised what thoughtful teaching means. As a theory, they will agree that formation of habit and character should be, perhaps, the first aim of a school, but, finding it troublesome to adopt as a working hypothesis, they too often attempt to console themselves by calling it faddism. They consequently fall into routine methods and lack initiative, and, failing to realise that inquiry is the *rock-bottom* method in all teaching, they thankfully accept rules that will save them the trouble of thinking.’

The reform of the training college curriculum is, therefore, the condition precedent to any satisfactory change in the character of the teaching given in our elementary schools; but it is no part of the work of the Committee to do more than to indicate in the barest outline the direction that such changes should take.

Of equal importance with the improvement of the training college

curriculum is the appointment of inspectors who have themselves received a thorough training in practical studies and experimental teaching. An inspector who may have obtained the highest degree at one of our universities does not necessarily possess the qualifications for a good inspector. With the abolition of the system of payment on results, the duties of the inspector have become much more onerous, and different qualifications are needed for the proper discharge of his duties. He must be well grounded in the principles and methods of elementary teaching, in order to be able to ascertain whether the teaching is sound and efficient. He must be able not only to criticise but to suggest, and his criticism and his suggestions must be founded on personal experience, and must be directed towards showing both how good work may be done and how errors may be avoided. Such inspectors might be selected from among head teachers, not necessarily of elementary schools, who have acquired experience in arranging courses of study, and have been found most successful in organising and imparting instruction on the lines laid down in this report.

It will be seen, therefore, that in order to effect reforms in our elementary education in the direction of giving due weight to practical studies, it is necessary in the first place that the curriculum of our training colleges should be modified by introducing, to a larger extent than has yet been done, laboratory and workshop instruction, and by directing the attention of the students to approved methods of experimental teaching. It is equally essential that sympathetic and experienced inspectors should be appointed, who will pay due regard to the correlation of the several subjects of instruction, and will see that undue prominence is not given to any particular subject on account of the comparative facility of teaching it, and who, above all, will endeavour so to direct the school work that it shall encourage thinking, and develop constructive ability and aptitudes for study on the part of the children.

Report of the Sub-Committee on Arithmetic and Mensuration, consisting of Professor H. E. ARMSTRONG, Miss A. J. COOPER, Mr. GEORGE FLETCHER, Mr. W. M. HELLER, Dr. C. W. KIMMINS, Professor J. PERRY, Mrs. W. N. SHAW, Miss EDNA WALTER, and Professor R. A. GREGORY (Secretary).

Recent Movements.

Since the report of a Committee on the teaching of elementary mathematics was presented to the Belfast Meeting of the British Association in 1902, decided changes have taken place in the nature and purpose of mathematical teaching in schools. The appointment of that Committee was the outcome of a discussion on the teaching of elementary mathematics opened by Professor J. Perry, F.R.S., at the Glasgow Meeting of the Association in 1901; and the attention thus directed to the need for reform led to the formation of similar committees by representative bodies of teachers and others interested in the improvement of mathematical teaching. Reports in which the general views expressed by the British Association Committee received support were also prepared by committees of the Mathematical Association and the Incorporated Association of Assistant-Masters. A syndicate appointed by the University of Cambridge, in December 1902, drew up schedules of propositions in demonstrative geometry and of constructions in practical geometry

suitable for the course of theorems proposed. The whole or parts of these schedules have been adopted as the basis of requirements in geometry for the Previous Examination at Cambridge, Responsions at Oxford, and the Local Examinations connected with these two universities. Other examinations which have been modified so as to found geometrical teaching upon experimental work with the use of instruments and numerical measurements and calculations are those of the London Matriculation, Army and Navy Entrance and Lower Civil Service ; with the result that in most secondary schools, not only in this country but also in India and the Colonies, the work in elementary geometry has altered greatly ; though it must be admitted that in actual practice reform has not gone far in the average school.

The recent improvements in the character of school geometry have been shared by other mathematical subjects, such as arithmetic, algebra, and trigonometry, to the advantage of them all. It is recognised that the work of accurate drawing and measuring, with numerical calculations, is far better adapted to the intelligence of pupils in schools, even when its practical value is left out of consideration, than a rigid system of deductive geometry. In good schools, geometry and trigonometry have, indeed, become in their earlier stages largely arithmetical, while algebra is introduced as generalised arithmetic ; and there is good ground for the belief that this rational and co-ordinated treatment of school mathematics will be generally adopted in the course of a few years.

The views expressed by the Committees of the British and Mathematical Associations as to desirable improvements in the teaching of arithmetic are subjoined, and also the recommendations relating to this subject contained in a report recently presented by a committee of the Institution of Civil Engineers. From these extracts it will be seen that there is a consensus of opinion among men of science, mathematical masters, and engineers, as to the fundamental importance of practical work, the need for simplification, the use of contracted methods and of logarithms in numerical calculations, and the omission of those parts of the subject which have no relation to the common experiences of life.

*Recommendations of British Association Committee.*¹

‘ In regard to arithmetic, the Committee desire to point out, what has been pointed out so often before, that, if the decimal system of weights and measures were adopted in this country, a vast amount of what is now the subject-matter of teaching and of examination could be omitted, as being then useless for any purpose. The economy in time, and the advantage in point of simplification, would be of the greatest importance. But such a change does not seem likely to be adopted at present ; and the Committee confine themselves to making certain suggestions affecting the present practice. They desire, however, to urge that teachers and examiners alike should deal with only those tables of weights and measures which are the simplest and of most frequent practical use.

‘ In formal arithmetic, the elaborate manipulation of vulgar fractions should be avoided, both in teaching and in examinations ; too many of the questions that appear in examination papers are tests rather of mechanical

¹ Extract from the Report of a Committee of the British Association on the Teaching of Elementary Mathematics. *Report of the Belfast Meeting, 1902, p. 473.*

facility than of clear thinking or of knowledge. The ideas of ratio and proportion should be developed concurrently with the use of vulgar fractions. Decimals should be introduced at an early stage, soon after the notion of fractions has been grasped. Methods of calculation, accurate only to specified significant figures, and, in particular, the practice of contracted methods, should be encouraged. The use of tables of simple functions should be begun as soon as the student is capable of understanding the general nature of the functions tabulated; for example, the use of logarithms in numerical calculation may be begun as soon as the fundamental law of indices is known.'

*Recommendations of Mathematical Association Committee.*¹

'1. The Committee consider that there is considerable danger of the true educational value of arithmetic and algebra being seriously impaired by reason of a tendency to sacrifice clear understanding to mere mechanical skill.

'2. In view of this the Committee recommend :—

'(a) That *easy viva-voce* examples should be frequently used in both arithmetic and algebra ;

'(b) That great stress should be laid on fundamental principles ;

'(c) That, as far as possible, the rules which a pupil uses should be generalisations from his own experience ;

'(d) That, whenever practicable, geometry should be employed to illustrate arithmetic and algebra, and, in particular, that graphs should be used extensively ;

'(e) That many of the harder rules and heavier types of examples which examinations alone compel us to retain in a school curriculum should be postponed.'

'With these as guiding principles the Committee are led to make the following suggestions :—

'*Arithmetic.*—3. That, as a preparation for contracted multiplication, pupils should, in multiplying, from the very first be taught to begin with the highest digit of the multiplier.

'4. That first principles should be carefully taught before vulgar fractions are begun, special stress being laid on factors with index notation and the use of the signs $+$, $-$, \times , \div , and of brackets.

'5. That, as far as possible, prime factors should be used in finding H.C.F., L.C.M., and square and cube roots.

'6. That much time should not be spent in teaching complicated vulgar fractions.

'7. That, in order to facilitate the teaching of decimals, a scale divided decimally (both in inches and centimetres) should be used for the actual measurement of lines; the scale should be subsequently used for the determination of areas and volumes.

'8. That in teaching decimals concrete examples should be taken from the metric system.

'9. That approximate work with decimals should be introduced early, and that recurring decimals should be treated in this way, the theory of recurring decimals being postponed to a later stage.

¹ Extract from the Report of a Committee of the Mathematical Association on the Teaching of Arithmetic and Algebra. *Mathematical Gazette*, July 1902.

'10. That the rule for cube root should be omitted.

'11. That those parts only of the English tables of weights and measures which are in general use should be taught; and that long questions in reduction (*e.g.*, square miles to square inches) should be avoided.

'12. That in money sums the system of decimalising money at sight should be largely used, and that answers should, as a rule, not be required beyond the nearest penny.

'13. That, in pass examinations in arithmetic, the use of algebraic symbols should not be prohibited.

'14. That rough checks should be constantly employed in arithmetical work.

'15. That in many cases a rough estimate might usefully *precede* the detailed work of an arithmetical computation.

'16. The Committee consider that the mental training afforded by arithmetic is largely impaired by the existing tendency of text-books to classify problems and to establish each type as a separate rule.'

Report of Committee of Institution of Civil Engineers.

The Committee of the Institution of Civil Engineers issued a schedule of questions to 120 representatives of (*a*) teachers in engineering colleges; (*b*) headmasters in secondary schools at which it was believed special attention was paid to scientific training; and (*c*) engineers not engaged in teaching. The following questions were submitted in mathematics, and the percentage of replies in favour or against is shown for each:—

'Is it desirable that the teaching of mathematics at school should be arranged with a view to attain all or any of the following objects?—

'1. The practical use of arithmetic, with the special object of obtaining correct results independently of the mere study of arithmetical methods.' (Yes, 81; No, 19.)

'2. The encouragement of the use of contracted methods.' (Yes, 91; No, 9.)

'3. The encouragement of exercises in mental arithmetic.' (Yes, 94; No, 6.)

'4. The teaching, at this stage, of what Professor Perry has called "practical mathematics," of the use of logarithms, of elementary trigonometry (limited, for example, to right-angled triangles), of the general ideas of projective geometry, including points and lines at infinity, and the use of the slide-rule.' (Yes, 85; No, 10; omit slide-rule, 5.)

'5. The elimination from instruction in mathematics of such matters as cube-root extraction and elaborate algebraic equations, which are purely intellectual gymnastics without any direct usefulness.' (Yes, 90; No, 10.)

The result of this inquiry led the Committee to make the following recommendations:—

'Instruction in mathematics should be given by methods differing considerably from those usually adopted in the teaching of this subject merely as an intellectual exercise. The geometrical side of mathematics should be fostered, and before they leave school boys should be conversant with the use of logarithms, and with at least the elements of trigonometry, including the solution of triangles. It is also of importance that

instruction in practical arithmetic should be carried further than has been generally the case hitherto, with the object especially of encouraging the use of contracted methods and operations in mental arithmetic ; and of encouraging also the expression of results with only such a degree of (numerical) precision as is consistent with the known degree of certainty of the data on which they are or may be supposed to be based.¹

Views of the Board of Education.

Evidence is not wanting that some educational authorities and examining bodies desire to encourage the rational and practical methods of teaching arithmetic in schools proposed in the foregoing extracts. The 'Notes for Teachers' issued by the Commissioners for National Education in Ireland contain valuable hints on the rational teaching of arithmetic, and the Scotch Education Department has adopted the new methods as the basis of work for the Leaving Certificate examination. The latest instance of this tendency is afforded by a Blue-book (Cd. 2638, price 8d.) prepared by the Board of Education in 1905, and containing 'Suggestions for the Consideration of Teachers and others concerned in the Work of Public Elementary Schools.' This publication includes a chapter on the teaching of arithmetic and three suggestive schemes of work for the various years of primary-school instruction. In the first of these schemes, addition and subtraction are applied to compound rules (money) before multiplication and division are taught ; in the second all the four simple rules are taught to begin with ; and the third scheme is based upon number as a means of measurement, whole numbers being taken first, while common and decimal fractions are afterwards introduced as successive refinements of a precise system of measurement. Though these schemes differ in detail as to the method of approaching the elementary processes of arithmetic, they have all been designed with the object of giving children clear ideas about number, a practical acquaintance with simple measurements, and confidence in the application of arithmetical operations to problems of everyday life.

The subjoined extracts from the chapter on arithmetic in the volume referred to indicate the principles upon which the Board of Education suggests the teaching of arithmetic should be based :—

'The simpler rules of arithmetic should be regarded by the teacher and by the children as being the result of the application of common-sense to operations with number as applied to concrete objects, money, weights, lengths, and areas.

'The teaching should, however, from the very first embrace problems and examples that require special methods for their solution, and scholars will thus be trained at an early age to use their intelligence, and not to place undue reliance upon the mechanical application of general methods.

'No difficult examples should be attempted by the scholars until the process to be applied has been thoroughly worked out by the class ; the necessary training in mechanical skill should be acquired rather by repeated practice in carrying out principles which the scholars thoroughly understand, than by attempting to work examples in rules of which the underlying reasons have not been firmly grasped.

¹ Extract from the Report of a Committee of the Institution of Civil Engineers on the Education and Training of Engineers (April 1906).

'Lessons in arithmetic will thus be of three kinds, which may be roughly described as theoretical, practical, and problem lessons respectively. In lessons of the first kind the scholars, under the guidance of the teacher, should construct the process or rule; the practice lessons may be devoted to the acquisition of neatness, accuracy, and speed in applying the rules which have been worked out; but the best proof of effective teaching in arithmetic is the ability of the scholars to work problems, and good results cannot be expected if undue attention is paid to abstract or difficult examples.

'Throughout the school the instruction in arithmetic should be made as realistic as possible. Infants should learn by the aid of actual objects, such as bricks, beans, cubes, or balls in a frame, to analyse numbers from three to ten, and combinations of these numbers not exceeding twenty, or, in other words, to find out in what different ways these numbers may be arranged. The use of sets of objects will make it possible from the very beginning to teach the children to add, rather than to count by units; the latter bad habit, once formed, is very difficult to eradicate, and will affect adversely the arithmetic throughout the school.

'Multiplication tables should not be learnt before they have been constructed and understood, and are therefore out of place in an infant school. When the children have mastered the principles underlying the simple rules and the construction of the multiplication table, it will be found advantageous to insist on great rapidity and accuracy in the mechanical operations involved.

'Even in the later stages recourse to concrete illustrations is advisable. For example, in dealing with areas and volumes, the idea of measurement by unit area or volume should be illustrated by building up areas or volumes out of unit squares or cubes. Physical illustrations of least common multiple and highest common factor may readily be devised by the teacher. Diagrams should be freely employed; and squared paper can be used with advantage in all exercises relating to measurement, and is the best means of introducing the idea of scale.

'To enable this practical work to be done every school should be provided with—

'(a) Foot-rulers graduated in inches and tenths of an inch, and also in centimètres and millimètres. (These should have square edges.)

'(b) Cords with feet, yards, and mètres marked upon them.

'(c) Imitation coins.

'(d) A pair of common scales with the smaller weights, such as ounces, pounds, kilogrammes, decagrammes, and grammes.

'(e) Measures of capacity, such as a pint pot.

'(f) Squared paper or tracing cloth.

'Plain paper also, owing to its cheapness and easy divisibility, will be found to be of very great value for illustrations.

'With this simple apparatus the scholar should be taught to perform the actual operations of shopping that involve the use of money and weights and measures, to measure in inches and centimètres the various objects in the school, and to estimate lengths and weights.

'There is much to be said for allowing a considerable interval of time to elapse between such experimental practice and the introduction of more formal numerical applications and rules.

'Certain elementary "rules" must be taught in all schools. These

should include simple sums involving money and the common weights and measures, vulgar fractions, decimals, and proportion by the method of unity.

‘In all cases an endeavour should be made to frame schemes of arithmetic teaching with some reference to the circumstances of the school ; and the course of arithmetic should include the drawing of lines and plans, practical measurements, and the construction of such things as cubic centimetres, if the scheme of hand and eye training taken in the school permits of this being done. In this manner this subject will be correlated with drawing, elementary physics, and the scheme of hand and eye training. It will also be possible to connect the sums with the subject-matter of other lessons. Thus, to be effective interest sums should be preceded by simple lessons on savings banks, relative safety of various investments, and usurer’s interest. Such sums should be limited strictly to simple numbers.

‘For older scholars exercises in land measuring are valuable ; and the occasional actual measurement of a field, or of the playground if no field is available, will be a useful supplement to indoor instruction. Even in the school it is possible to find suitable practical exercises in the measurement of bulks, weights, and areas of common schoolroom objects.

‘For both older and younger girls problems relating to domestic economy and thrift are especially useful, and in country schools the sums should frequently have reference to the produce of the farm and the field. It is also desirable that, as far as possible, the current market price of the commodities named should be used in the questions.

‘The commercial applications of arithmetic commonly found in text-books could generally be advantageously replaced by algebra, practical geometry, and the mensuration of the simpler solids and surfaces. The division of arithmetic and algebra into distinct subjects is much to be deprecated. Much will be gained by the very early substitution of letters for numbers in some of the ordinary arithmetic, and by the early introduction of the ideas of negative quantities and simple equations.

‘Practice should thus be of five kinds :—

‘(1) Preparatory experimental exercises to show the necessity and meaning of what is coming.

‘(2) Numerical exercises, in the rules and processes that are being taught, dealing with very small quantities.

‘(3) Exercises combining these rules with others, and also containing larger numbers.

‘(4) Recapitulation, including oral (or, where possible, written) answers to questions on previous work. These should be given with as little technical nomenclature as possible, and without ciphering abbreviations ; *i.e.*, each figure should have its full value assigned to it.

‘5. Exercises in pure ciphering, to cultivate speed, accuracy, and the habit of concentration.

‘It is not, however, necessary that large quantities should be involved. Accuracy is not obtained by working long sums, but is rather the result of mental concentration and experience.’¹

A course of work conceived in the spirit of these suggestions would

¹ ‘The Teaching of Arithmetic.’ From *Suggestions for the Consideration of Teachers and others concerned in the Work of Public Elementary Schools*. Board of Education. Cd. 2638, 1905. Price 8d.

meet with the approval of most advocates of reform in the teaching of arithmetic in elementary schools. What is now required is that the principles described above should be raised from the plane of pious opinion to that of actual practice. It is not sufficient for the Board of Education or any other body exercising control over the work of elementary schools to point out desirable methods of teaching arithmetic, when it is well known that in most schools no change will be made until it is insisted upon as essential to efficiency. At present the suggestions issued by the Board are regarded merely *as suggestions* by the teachers who have taken the trouble to read them, and therefore outside the sphere of practical politics. The futility of issuing a book of maxims without insisting that they shall be acted upon is obvious to anyone familiar with teachers and schools. There may be differences of opinion upon some of the details of the arithmetic schemes included in the 'Suggestions' but the spirit of the extracts given above leaves little to be desired; and if educational authorities would state in unmistakable terms that they will only countenance work in arithmetic founded upon the principles suggested by the Board of Education, a marked improvement in the teaching of the subject would soon be seen.

It is undesirable to give here a detailed syllabus of a school course in arithmetic, but a useful purpose may be served by pointing out some existing defects and indicating directions in which improvements are required. Experienced teachers know the intellectual capacities of children and many of them follow methods of instruction which leave little to be desired. In general, however, arithmetic is not made a practical study but a miscellany of processes of doubtful origin and utility. To indicate some of the furbelows which may be usefully discarded and to encourage the adoption of a more reasonable treatment of the subject is the chief object of this report.

Fundamental Principles.

So far as possible, all reasoning in arithmetic should be from the concrete to the abstract. Pupils should not be drilled in applying rules they do not understand, but should learn by the manipulation of objects, paper-folding, the measurement of lines or consideration of other concrete instances, what is meant by simple arithmetical processes and should then be led to arrive at generalisations expressing in abstract form what they have found to be true in the concrete. In other words, the rules should represent results of experience, instead of being academic statements of the order or method in which arithmetical operations should be performed. Excessive precision in the manipulation of large numbers, or rapidity of working should not be considered more important than the development of reasoning powers encouraged by dealing with things instead of words.

The practice of teaching arithmetic as a collection of devices under different headings, from which a choice has to be made for the solution of any particular problem, cannot be too strongly condemned. Every teacher is familiar with the pupils who want to know whether they should multiply or divide one number by another in a given sum in order to obtain the correct answer; when this state of things exists it is evident that the calculations are meaningless. When the first four rules are grasped and the meaning of a simple fraction is understood, as the result of familiarity with the subdivisions of a penny or an inch, decimals

may be profitably introduced by measurement ; ratio then presents no difficulty and proportion is merely the equality of two ratios. *No other rules are required in simple arithmetic ; in particular, the ' rule of three ' should be avoided, as an obstacle to clear thinking and an offence against the common-sense of a child.*

Methods of Approach.

Attention should be given to local value of digits at the commencement of the use of numbers as symbols. In teaching local value, use should be made of bundles of small sticks in tens, pigeon-holes with separate compartments for bricks or other things representing units, tens, and hundreds, or separate rods upon which nine or ten beads can be placed but no more. When the principle is understood, the expression of it by figures in different columns should be taught but not before. Subtraction can be taught at the same time as addition by treating it as complementary addition. In performing simple multiplication, it is doubtful whether children at the beginning should be taught to multiply first by the left hand or highest digit of the multiplier instead of following the usual method. The ordinary process appears to be simpler for young children to understand, and it follows naturally from short multiplication. Pupils who learn contracted multiplication will do so later, when the change from multiplying first by the right-hand digit to the left-hand digit of the multiplier will present little difficulty.

After acquiring familiarity with the processes of short and long division, bright children may with advantage use the Italian or compendious method of working long division, by which remainders only are written down, these being found by complementary addition. The study of formal vulgar fractions should not be commenced until work has been done with decimals ; and there should be no sums involving fractions until clear ideas as to their meaning have been obtained from concrete examples and measurements. By the time children begin written work with fractions they should be so familiar with subdivisions of the inch and centimètre scales that rules for the addition, subtraction, multiplication and division of fractions can be comprehended without any difficulty. With squared paper divided into tenths it is easy to show graphically the products of such numbers as $2 \times 3\frac{1}{2}$ or $3\frac{2}{3} \times 2\frac{1}{2}$; while by similar graphic exercises pupils will readily see the absurdity of adding mixed numbers by converting them into fractions, and understand that the product of two proper fractions is numerically less than either. The great advantage of work of this kind is that it *enables the pupils to visualise simple principles.*

Practical Work Essential.

Familiarity with the use of a rule divided into inches and tenths or centimètres and millimètres enables pupils to acquire a sound knowledge of decimals unconsciously ; and at the same time they learn the significance of place value. Work of this kind can be introduced quite early without any difficulty. There is no need for any elaborate explanation of units and subdivisions if pupils are given sufficient opportunity for practical work with decimal scales and squared paper divided into tenths ; while the difficulty as to the place of the decimal point in later calculations disappears, because clear ideas have been obtained of its meaning by

numerous measurements. When percentages are reached, they may be usefully considered as decimal quantities as well as common fractions. It should be remembered that our monetary system admits of convenient decimal treatment; for, expressed as decimals of 1*l.*, we have 2*s.*=0.1; 1*s.*=0.05; 6*d.*=0.025; 1*d.*=0.004 (about) or 0.0042; and $\frac{1}{4}$ *d.*=0.001 (about). With a little practice, therefore, it is easy to decimalise money at sight.

Measurements of lines, areas and volumes may be introduced much earlier than usual. Sets of hardwood models can be obtained at a low cost and should be put in the hands of the pupils to examine, measure and sketch, the measurements being expressed in decimals. By work of this kind and other measures of physical quantities, arithmetic may be correlated with scale-drawing, geometry and the use of symbols in formulæ.

Concrete Experience should precede Calculation.

Too much attention is usually devoted to currency calculations or money sums, while decimals, measuring and weighing, and work with realistic devices which teach the principles of arithmetic, are neglected. Children should not be troubled with any computations of this kind until they have fingered boxes of imitation coins and have clear ideas of the value of the tokens of commerce in buying and selling. When they are familiar with the relative values of coins and are able to answer simple questions orally, it is time enough to introduce work to be done on paper. If this plan is followed there will be fewer instances of children working sums involving amounts up to, say, 100*l.*, while they do not know what change to expect if they spend 3½*d.* out of 1*s.*

Tables of money, like tables of length, capacity or weight, should be based upon actual work and sense observations, even if they have to be committed to memory afterward. A working knowledge of our common weights and measures may be thus obtained; and the many tables which cannot be dealt with in this way ought not to be considered in the work of elementary schools. Tables and sums relating to troy weight, apothecaries' weight, dry or corn measure and apothecaries' fluid measure might, therefore, well be dispensed with; the time thus saved might be given to work of which the pupil understands the significance. The cardinal principle in the teaching should be that the pupils are practically acquainted with all the weights and measures involved in their calculations, for without this knowledge or experience the work in arithmetic becomes merely a matter of mental gymnastics. Upon this point it is satisfactory to record that the latest 'Regulations for the Instruction and Training of Pupil Teachers'¹ specifically exclude from the syllabus of arithmetic troy and apothecaries' measures, rules for finding square and cube roots, practice, ratio, proportion (except by the unitary or fractional method), stocks and shares, true discount, scales of notation, foreign exchanges, compound interest, recurring decimals and complicated fractions.

Value of Mental Exercises.

In classwork there should be plenty of oral exercises and practice in mental arithmetic, in order to cultivate quickness and intelligence. It is

¹ Cd. 3012; price 2½*d.*

a good plan to make pupils arrive at *rough answers to problems mentally before working out a calculation in detail*, for in this way they are less liable to be content with absurd answers. Until rough mental results can be arrived at, it is of little use to proceed with exact calculations. Moreover, in actual life approximate values quickly obtained from given numbers are constantly required. The value of mental work in class cannot be too strongly emphasised: no teaching is satisfactory in which these exercises do not occupy the most important place.

Co-ordination with Experimental Work.

The co-ordination of arithmetic with any work in elementary experimental science carried on in schools is very desirable. Simple experiments in mechanics, physics, chemistry, and meteorology provide results that afford practice in working with numbers to which pupils can attach definite meanings; and calculations of this kind have the advantage of giving confidence in the applications of arithmetic to problems of everyday life. The arithmetical work thus becomes part of a student's mental machinery, instead of being regarded as a set of disconnected rules, leading to results which have no real meaning outside the classroom. In the upper classes especially, measurements and quantitative work in elementary science should provide a large part of the material for arithmetical exercises. The work may deal with such subjects as averages, strengths of mixtures, velocity, conversion of thermometer scales, approximation, specific gravities; many examples of the application of graphical methods should be given.

Graphs and Tables.

In working out arithmetical results of simple experimental work in science and in solving problems, particular attention should be paid to (1) the limits of accuracy and (2) the shortest method of arriving at a correct result. Expressed in another way, pupils should understand the degree of approximation of the data supplied and should employ the best tools available for working out a solution. Where squared paper provides the quickest or easiest means of getting a result of sufficient accuracy, it should be adopted; but there is little advantage in using this graphic method in cases in which the solution can be obtained more satisfactorily by simple arithmetic. Frequent comparison of results obtained by graphs and by calculation will soon show the degree of approximation which can be reached on squared paper and will indicate that in many problems graphic methods are the best to employ. It should also be remembered that, even though arithmetical operations may give a result more quickly than graphs, the advantage of the graphic method is that it provides an illustration of a principle or relationship which is more easily remembered than a set of numbers.

Advantage should be taken of numerical tables such as are used by men in the office or workshop. Tables of shillings and pence as decimals of £, tables of compound interest, squares, cubes, square root and cube root, reciprocals and other values in common use by practical men, can be consulted as labour-saving devices. Tables of logarithms might also be used, as they are not so difficult to understand as much of the abstract work at present done in schools.

Co-ordination with Geometry and Algebra.

Whatever geometry admits of arithmetical exercises or illustrations should be introduced where it is of use. Even if formal geometry and algebra are not taught in elementary schools, there is no reason why they should not be used as graphic and generalised arithmetic respectively where the circumstances of the school and staff are favourable. This has been done in some schools and from the work that has been submitted to us it is evident that success has been achieved. For instance, at the Newhall Council School, Burton-on-Trent, the experimental geometry scheme for Standards V. and VI.—that is, for boys of about ten to twelve years of age—is largely arithmetical in character. The course includes the construction and measurement of simple geometrical figures and the chief properties of these figures of service in mensuration are illustrated by the results. At the New Seaham Boys' School, also, a decidedly practical character is given to the work, which includes measurements of lengths, areas and volumes, drawing plans to scale, simple surveying, the use of such instruments as calipers and the millimètre screw-gauge and of tables of logarithms.

Algebra as generalised or shorthand arithmetic should be introduced when the use of algebraic symbols in expressing relationships briefly or simplifying problems is appreciated. Pupils will soon learn to write algebraic expressions of arithmetical rules or relationships; and when they understand clearly the nature of a formula and the principle of proportion as the equality of two ratios, they are in a position to make intelligent use of the simple formulæ and tables relating to mensuration, physics, chemistry and engineering to be found in pocket-books used by practical men. They will be far better employed in the evaluation of selected formulæ, using tabulated data from such works, than in continually working at tiresome frivolities of currency. In actual business, boys are not likely to be concerned much with calculations involving interest, discount or other elaborate commercial calculations; it is much more desirable to give them a practical and sensible knowledge of the principles and tools of arithmetic than to drill them in the use of rules which they will rarely have an opportunity of applying in their daily work. If a boy has been taught arithmetic by scientific methods and not as a collection of artifices, he will have little difficulty in responding to the demands made upon him when he leaves school, whether he enter the office or the workshop.

Correlation of Mathematical with other Work.

At present much time is wasted in schools by teaching the various subjects separately; not only might time be saved but the work might be made far more interesting and far more profitable to children, if it were often to involve a variety of exercises and the complete working out of some scheme. Experiments are needed in this direction. The following suggestions are made by Professor Armstrong for a series of lessons:—

Suggested Lessons on Ages.

'Ask the children their ages and write upon a blackboard a list of names, with the age in years and months in order of age. Some may

have difficulty in stating their age, at all events in stating months as well as years. Ask each child to write a little letter stating when it was born and how old it is at the date of writing. These letters will serve as literary compositions and can be more or less discussed as English and writing lessons. They will also show how far the children understand the division of the year into months and days and will afford an opportunity of giving lessons on this subject.

‘Have the letters read out one by one by their writers, so that each child may make out a table in which the members of the class are arranged in the order of age, the age being given in columns headed years and months and also, in a second column, in years with the number of months written after the year number but separated by a dash; thus—A. B., 9-4 years, meaning 9 years 4 months.

‘Later on, the children may be led to understand how the month numbers in the second column may be converted into fractions, thus— $9-4 = 9\frac{4}{12}$ years $= 11\frac{2}{3}$ months. The length of different months and of the year can be discussed at a later stage, when they are asked to state their age in days.

‘As soon as the age tables have been drawn up—in itself an exercise in neatness and the arrangement of figures, &c.—draw attention to the difficulty the eye has in taking in the information such tables give and the need of some picture which could be more easily understood. Ask for suggestions. Then introduce the foot-rule and point out how the inch may be taken to represent, say, a year; next let each child cut out a strip of plain or coloured paper to scale to represent its height; by pasting these on a sheet of paper pinned to the wall or blackboard, a diagram would be obtained representing the relative ages of the children. The strips might be arranged in several ways—(a) in the alphabetical order of the children’s names; (b) in the order of their ages; (c) in the order of their heights. Sooner or later each child should draw or colour such a diagram on card or drawing-paper. The absence of a scale would make it necessary to measure the length of the strips to find out the age; a graph should therefore be made by drawing upright lines at regular distances apart, lines being also drawn across the paper to serve as a scale. Then squared paper should be given out and its use explained; the ages should be indicated on it only by dots. A line should then be drawn through the dots to show the variation from child to child. The conception of a middle, mean or average age should next be developed and indicated on the diagram by a line drawn across it through the various dots. The departure from the mean in the case of each child should be deduced, first by measuring and then by calculating. Throughout such work accuracy should, as far as possible, be insisted on.

‘At this stage the height of each child should be ascertained and, if possible, its weight. Graphs should then be made as before, showing the height and weight of each member of the class in comparison with age. Curves should also be drawn to bring out the relationship between the three. By repeating the observations at stated intervals a record of growth would be obtained. It will be desirable to obtain each child’s actual weight. To do this, if an undressing-room be not available, they might be weighed in ordinary attire one day and the next day they might bring all the clothes they had on at the time of weighing in a bag provided for the purpose; the clothes could then be weighed and their weight deducted.

'Other measurements should then be made and recorded in a similar way, such as size of head and length of foot ; the relation of foot-length to body-length and of body-weight to body-length should then be worked out.'

It is very important that practical exercises should be devised which will bridge over the gap between Kindergarten work and the time when children can handle tools. Much may be done by paper cutting and folding and by shaping cardboard and by building up squares, triangles, &c., into boxes.

The tendency of teachers in carrying out such work is to fly too high ; the supervising teacher will need to criticise in tactful and guarded terms, which will appeal to the class as well as to the instructor. The following is offered by Professor Armstrong by way of suggestion :—

Remarks by Mr. Square.

'I have been looking through a number of very neat exercise-books in which an account is given of my humble self. I had no idea that so much could be made of me. The accounts are almost as exciting to read as "Alice in Wonderland" and make me wish to ask a great many questions.

'1. First, I should like to know what the term "Practical Geometry" on the book-covers means. I do not like words that I do not understand and shall be content to wait some time before I attempt to understand this term. It seems to me that you are studying *shapes* and *sizes* and that you are finding out all you can about me and my relations, so that you may write a story about us. I shall be content if you call your story "Mr. Square and his Relations, or Shapes and Sizes."

'2. The story-books I read are divided into chapters. Will you not write your story in story-book style? Look at a story-book and see how it is arranged. Has it not a title-page? And then, on the first page I see a heading, "Chapter I.," below this there are some words to show what the chapter is about.

'3. I suppose the heading to your first chapter will be simply "Mr. Square." Now, I should like you to begin by telling me how you first came to know me and why you are interested in finding out all about me. Remember what the Mock Turtle said to Alice: "No wise fish would go anywhere without a porpoise." I hope you know the passage and understand its meaning. If not, read it at once and read it again and again and never forget it. To attempt to do anything *without a purpose* is very wrong.

'I suppose your teacher introduced me to you, perhaps by holding up a piece of paper, telling you it was cut in the shape of a *square*, asking you to look at it and measure it and then to find out in what different ways you could fold it. And evidently you were asked to write an account as you went on with the work of all you saw and did and thought, so that you might be able to describe me. If you had told me this at the beginning of your story it would not now be necessary for me to ask for information.

'4. I am very glad to see that you each wish to have me with you, so that you may be able to study my character closely. You will be surprised, I can assure you, as you learn to know me more and more, how

much character there is in me and how very useful I am. But I cannot understand from your descriptions how you have cut me out, although I must admit that most of you have cut me out very cleverly. Did you look at me long enough to know me? I fear not. Although I look so simple, I am not easy to make.

'You say I have four sides, each 4 inches long. Following your description, I have cut out a piece of paper with four sides, each 4 inches long, but it has not my shape at all. On looking at it you will say, I think, that *my* corners are all of the same size and that the corners of the piece I have cut out are not square corners. I see this is so. But how, then, are square corners to be made? What is the difference between square corners and those of the shape I have made? Look at them well and try to tell me.

'5. I notice that some of you say not only that my sides are equal but also that my angles are of the same size. What are angles? Are they corners? Everybody knows this latter word, but angle is not a common word. It would have been kind if you had told me, when using the word for the first time, what it meant and where it came from. I have looked in the dictionary, and find it is from the Latin word for a corner—*angulus*. Why do English people use Latin words? Can you tell me? In future, if you can, when you use new words tell me what they mean and what language they come from.

'6. I notice that some of you not only call my corners angles but that you speak of them as right angles. What does this mean? Are other angles than mine wrong angles? I must object to be called by names I do not understand and which need so much explanation. It will be much better at present for you to call corners such as mine square corners. When you have found out how to draw my corners properly we will talk about other kinds of corners.'

Recommendations.

The following recommendations may be considered as supplementary to those made by the British and Mathematical Associations, and reprinted earlier in this report :—

1. It is essential that a knowledge of arithmetic should be based upon exercises involving the manipulation and measurement of actual objects. At every stage practical work performed by pupils individually should be considered as of far greater importance than complexity of calculation.

2. Great attention should be given to fundamental principles and any rules required should be generalisations from work done by the pupils. No written calculations should be required until pupils are able to give mental or approximate answers to the sums set. Frequent oral exercises are therefore necessary.

3. Complicated calculations presenting purely artificial difficulties should be avoided. There should be a general simplification of the rules and exercises usually included in school arithmetic and more work with small numbers to illustrate arithmetical principles. Less attention should be given to currency calculations and more to the study of arithmetic experimentally, in order that pupils may learn by their own experience and acquire intelligent ideas of dimensions by realistic work and

measurements of shapes and sizes. Mechanical use of the 'rule of three' should be avoided; and importance should be attached to giving clear ideas of ratio.

4. Every pupil in an elementary school should perform, in the course of his work, numerous practical exercises with imitation coins, inch scales divided into common fractions and decimals and scales of centimètres and millimètres, balance and common small weights, both metric and British, common measures of capacity in both systems, compasses, dividers, protractor, and squared paper. In the highest standards logarithms and other labour-saving methods of computation may be used, where the circumstances of the staff permit these methods to be introduced with profit.

5. The work in arithmetic should be co-ordinated with that in elementary science, so that problems suggested by the science teacher or results found in the laboratory may provide exercises in computation in the classroom.

6. In testing proficiency in arithmetic, an intelligent knowledge of the operations and familiarity with practical work should be considered at least as important as numerical accuracy.

7. No artificial distinction should be recognised between arithmetic and algebra. Symbolic notation, the use of signs, substitution of numerical values for symbols, transposition of terms and the plotting and solution of a 'straight-line equation' should form part of the arithmetic programme of the sixth and seventh standards. Wherever algebraic and graphic methods save time their use should be encouraged.

8. Geometry should be co-ordinated with arithmetic by such work as measurements of lines, areas and volumes, construction and measurement of simple geometrical figures, construction and measurement of paper models, scale drawing and the representation of variables by graphs.

Report of the Sub-Committee on Nature Study, consisting of Mr. R. H. ADIE, Miss L. J. CLARKE, Mr. A. D. HALL, Mr. H. RICHARDSON, and Mr. HAROLD WAGER.

1. *The Object of Nature Study.*

We regard the direct study of Nature as a sound foundation for all training of the observing and reasoning powers, and we consider that it is a subject particularly suited to elementary schools under present conditions.

Of the many subjects available for Nature study we regard the study of the living plant from the experimental side as most suitable for elementary schools. It satisfies the following important requirements: (i) It can be made experimental, and most of the experiments are such as can be repeated by the pupils. Some experiments are of a continuous character and afford training in measurement and recording. It is wise to emphasise the quantitative side of many of the experiments. (ii) The subject forms a connected series of lessons, the later work developing naturally out of the earlier. (iii) The experimental teaching in school is easily linked to the outdoor life of field and hedgerow with which country children are familiar; it naturally introduces observations on animal life, soils, the weather, &c., and it is readily illustrated by practical examples drawn from the work

on the garden and on the farm, so that the children learn that school work may have a bearing on their after-life.

The development of Nature study finds a natural starting-point in the object lesson.

2. *The Object Lesson.*

(a) *The Objects Set.*—Several teachers of repute have recently drawn attention to the cycle of the seasons as the best ruling idea for the arrangement of any scheme of Nature lessons. And this we heartily endorse; there can be no better guarantee that the teaching will really be based on observation and experiment. In summer there is endless material. In winter it is more difficult to realise the opportunities of the moment; but the long nights favour the study of the stars, the bare earth suggests the study of soil and rock, the weather is always a source of anxiety, the frost without and fire within suggest lessons on heat and cold.

The teacher who is planning his lessons some months beforehand will therefore require a calendar indicating what topics are likely to be in season. Gardener's calendars are given away as advertisements by several firms of seedsmen. The current Whitaker, or better still the 'Nautical Almanac,' gives warning of impending celestial events. The average time of flowering of wild plants has been observed and indexed under the heading 'Phenology.' Several naturalists' calendars have been published. A farmer's year-book will be useful in the country. From these and from his own experience a teacher can compile a calendar of possible topics from which to choose his lessons.

(b) In this connection we append a *Nature Study Calendar.*

JANUARY.

Trees; twigs, branches, bark. Evergreens.

Snow. Ice. Frost.

FEBRUARY.

Bulbs, corms, tubers.

Catkins.

The lengthening day.

Flooded rivers.

MARCH.

Development of birds.

Seeds and seedlings.

Wind. Equinox. Spring tide. Full moon.

View from hill-top. Making maps.

APRIL.

Opening buds.

Rain. Clouds.

Flowers. Migrant Birds. Birds'-nests.

MAY.

Experiments on plants. Rate of growth.

Development of hens' eggs in incubator.

Insect life. Bees.

Dew.

JUNE.

Experiments on plants. Assimilation. Butterflies.

Pollination of flowers.

Longest day. Solstice.

Haymaking.

JULY.

Plants.

Caterpillars.

AUGUST.

Heather.

Chrysalis.

SEPTEMBER.

Harvest.

Seeds and seed distribution.

Equinox. Shortening days.

OCTOBER.

Fruits. Germination of seeds.

Falling leaves. Rain. Rivers.

Planets and constellations.

NOVEMBER.

Fog.

Stones.

DECEMBER.

Snow. Ice. Frost.

Solstice. Shortest day.

(c) *The Method.*—The object must be present if the lesson is to be real, and the supply of material must be liberal. If the elephant can only be represented by a picture, that is a reason for giving lessons about some-

thing else until it is possible to adjourn to a menagerie. Where flowers or stones are required let them be provided in sufficient quantity to give every child a specimen. Let these be distributed at once, so that the children may start with their own observations. This will require training, and the teacher will at first spend much time in discussing what is seen with the children.

A good way of ensuring that children do really observe is to ask them to make drawings from the specimens in front of them. Drawings can be more rapidly corrected by the teacher than written accounts; but written accounts should also be asked for. If the first attempts of the class are disappointing, the teacher may put his drawing on the blackboard before them, then rub it off, and ask them to try again from the specimen, but while the drawing is being done there ought not to be any sketch on the blackboard which might serve as a guide.

The dictation of notes and the copying of diagrams from books or from the blackboard we condemn. We think that a good deal of time is now being wasted on dictation and copying, to the great prejudice of the name and fame of Nature study. The children should be asked questions before they are told the answers; and their verbal answers may be used to draw up a description of the object before them. Afterwards they may try to do the like for themselves.

For the younger children the topic of the object lesson may very well be chosen from those available at the time, and the lesson may be used as a training in the construction of sentences embodying their observations. Children may be encouraged to make their observations in turn.

For the upper standards teachers will rightly wish to plan some more systematic course. But the plan should retain some elasticity in order to fit with the season. If the different stages of the opening chestnut-bud are to be watched, they must be seized almost to a day, and yet one year they may open a fortnight before or after their date on the previous year. If the natural order *Rosaceæ* is being studied, we must remember to gather roses while we may.

In training a class to manipulate experiments it is a good plan to ask children in turn to come up and try to do things before the class. In this way interest is stimulated, attention is drawn to probable mistakes, and the teacher feels when the class is ready to start individual work.

(d) *The Syllabus*.—We have no syllabus to offer: there is no old syllabus to which we wish to adhere, nor any new one which we wish to put in its place. Any teacher who wishes for a syllabus will find that plenty of good ones have been published already by the Board of Education, and any teacher who has found the spirit in which to study Nature will be able to make a better syllabus for himself, new every year. Salvation will not come by any syllabus; and of every syllabus we would say: 'This syllabus must be regarded as suggestive only, and not inclusive. Every teacher should be free to take part of the syllabus in detail rather than the whole superficially, and free also to go outside the syllabus. A syllabus may be useful as a humble servant, but it is a very bad master.'

The danger of a syllabus is lest the general topics prescribed, such as types of fruit, inflorescences, shapes of leaves, should be studied in advance of the real concrete plant, whereas all the work should be done from the actual living specimens. The pupil himself, if possible, should carry on the experiments. At all times plants should be studied as living

things and not as dead material. So too with physiography, the syllabus should be illustrated by perpetual reference to the school district—indoors by experiments, out of doors by walks and excursions in the neighbourhood.

3. *The Supply of Material.*

This must be abundant, in good condition, and sufficiently uniform in character for class teaching. The last condition is not always fulfilled when the children collect for themselves, and when classes are many and large the teacher may find the quantity required too heavy to collect himself. Botanical material is not expensive when compared with the apparatus or chemicals deemed reasonable for chemical laboratory work. Education committees might arrange with nurserymen for wholesale prices, and then ask teachers to order direct on special forms with suitable limits for expenditure, *e.g.*, not exceeding 1*d.* per pupil per hour. The Kyrle Society's action has been most welcome, and the Committees of Public Parks can greatly assist.

4. *Outdoor Work.*

While plant life forms a very generally suitable indoor subject for elementary schools, there should be a good deal of flexibility about the nature of the accompanying outdoor work. With some teachers gardening, with others field botany or geology, forms the accompaniment. The teacher should be encouraged to develop a speciality according to his own tastes and the advantages or restrictions of his locality. Thus for a school among osier-beds the natural history of the willow is an admirable subject.

It is now within the power of all elementary teachers to take the school out of doors for a lesson and to count it in the time-table. Inspectors are sympathetic, and it is frequently done.

Every syllabus that includes the shadow of a stick at noon or the nightly turning of the Great Bear about the Pole, prescribes topics which it may be impossible to teach practically in lessons held at 2.30 in the afternoon. But this is just the reason why the routine of school work may suitably be broken to allow children to witness exceptional natural phenomena—a great flood, a high tide, or an eclipse of the sun—phenomena whose times of occurrence are not within our control.

In schools which possess a garden much can be done by the children. Simple experiments in assimilation, pollination, grafting, &c., can be tried. Where classification is studied, the making of order beds by the children is a great assistance. When it is impossible to work in a garden experiments may be carried on in window-boxes.

Excursions should be made to lanes and fields at all times of the year. Even in towns it is possible to study the branching of trees and unfolding of buds and to become familiar with the aspects of different trees in winter, spring, and summer.

To give definiteness to outdoor work some questions to be answered may be set before starting a walk, and answers to them written out afterwards.

Is it not possible that some city teachers, anxious to gain in Nature lore, would find that a few years spent in working at a country school

would give them invaluable opportunities of studying things in the open which previously they had only heard of in lectures or read about in books?

The extent to which the children of the city may be usefully and economically transported to the country for purposes of education remains largely unexplored. The Sunday schools have demonstrated the possibility of taking large numbers into the country for a single day's outing. The Children's Country Holidays Fund and the various seaside camps held during the summer show how to arrange for a few weeks of holiday.

These arrangements have in view chiefly the great need for fresh air and holiday. But of definite, directed educational use of the country we hear little as yet. The question of extending the advantages of a country boarding-school education to the children of the poor is coming up for discussion. One large city is already casting longing eyes on the country school-houses standing empty during the holiday weeks whilst the town children pine for fresh air. A good deal might be done by hearty co-operation between city and county educational authorities. Schemes are mooted for sending out whole classes of city children under their own teachers for a few weeks at a country school. Some voluntary help and organisation, with special funds subscribed *ad hoc*, will probably be necessary to carry these schemes through.

We hear of one London Board school taking its scholars far afield, and a provincial Board school has shown what brilliant use may be made of the school-journey. Some of our secondary schools are emphatic as to the usefulness of such journeys lasting more than one day. In Switzerland they have a much more recognised place as a part of general education. In our own elementary schools the difficulties are largely financial.

5. Collections.

The collecting instinct is sufficiently strong at the ages we are discussing. The collector is often a naturalist in embryo; he is, therefore, to be judiciously led into the paths of progress. In certain directions—notably bird's-nesting—restraint more than encouragement may seem necessary; but numerous recent books illustrated by photographs of birds'-nests show the possibility of teaching children to watch without destroying. The general line is to wean a boy gently from mere collecting to collecting with a purpose; to collecting and observing, and then to the collection of observations in a note-book kept for the purpose. Collecting is a great help to accuracy of observation, and the boy who brings back a collection of pebbles from the seashore or of grasses from a hayfield will know far more about what he carries in his hand than a schoolfellow who has never troubled to pick up anything. Children may be encouraged to try how many different sorts of wild roses they can find along a country lane, and to write notes on their differences.

The collecting instinct is a great motive power, if rightly directed. It should be used to solve special problems. And if prizes are offered they need not be for the largest or best collection of wild flowers, but for collections illustrating insect pollination, or seed dispersal, or climbing plants.

6. *Defects in the Present System.*

The Sub-committee desire to express their cordial recognition of the efforts of the Board of Education and of the Board of Agriculture to encourage real science work, and they are also aware that much excellent Nature study work has been and is being carried out, but several serious defects have been found, among which we note :—

(i) An attempt is made to cover too much ground ; hence experiments and measurements are shirked because they take time and involve preparation on the part of the teacher. Experiments are described instead of performed, and a drawing on the blackboard takes the place of realities. This is the commonest and most vicious defect in such teaching.

(ii) Unsuitable subjects are often taken, especially with the idea of being practical. It is no use dictating notes on haymaking to a class when there is no opportunity of taking part in the process.

(iii) On the other hand, there is a great lack of system. A lesson on opening buds is followed by one on tadpoles or on the motions of the moon. The topics are all in season in March, but for upper standards we think the course should become more systematic.

(iv) When a definite course is chosen it is often overloaded with classification. The teacher seems to have the fear of a possible examiner before him, and is afraid to omit anything. Science is too often supposed to consist of big words. 'Amaryllis, fruit, a bilocular loculicidal inferior capsule,' need not appear in the note-book of a boy of thirteen.

(v) Gardening should never degenerate into the mere employment of cheap child-labour on the teacher's garden without consideration of its use to the child. The criterion of suitability should be the educational value of the subject and how far it can be made to develop the child's mind.

(vi) The size of the class is a most important consideration if we wish the children themselves to carry on experimental work. Experience points to from twenty to twenty-four pupils doing practical work in a laboratory as quite enough for one teacher. With larger classes the teacher has to arrive at a compromise between experiments done by each individual and experiments done by the teacher for demonstration, and the size of the class, if too large, makes it difficult to organise any work of a new character—anything different from sitting at desks, listening, answering in chorus, writing from dictation, learning by rote, or working sums of a monotonous character ; in fact, the limitation of the size of the class should be regarded as one of the educational reforms at present demanding attention.

(vii) A teacher is generally called upon to teach such a great variety of subjects that it is not reasonable to expect him to be an expert in each. Teachers should be encouraged to take as special subjects whatever they can do best.

7. *The Training of Teachers.*

These defects would be largely obviated if the training of teachers in the subject could be made more systematic. At present there are four kinds of agencies at work : (A) Saturday classes, (B) summer meetings for existing teachers, (C) the training college course, (D) teachers' Nature study clubs. A general elementary science course which includes some botany is now compulsory in the training college course. Nature study,

gardening, &c., can be taken as special subjects in the second year. Not many training colleges took up the subject in 1903, and even those were much discouraged by the magnitude of the work involved in the syllabuses which were attempted. In our judgment every training college should give such instruction in the method of observation and experiment that the future schoolmaster would be put on the right track, and could later on work out his own subject. Teaching may be wholly opposed to the spirit we strive to inculcate if Nature study is treated as another, and a very cumbrous, subject to be got up for examination. The training college student is very heavily taxed; he does not need more subjects; he does need to be taught the right method of going to work.

The more training in scientific research the teacher has had the better. If he has only been getting up book-work in the hope of passing examinations his influence may be less helpful. Where the teacher is not in sympathy with scientific methods of inquiry he cannot be expected to see how to put the children on the right road. It is important that the instruction should not become stereotyped, and a course for teachers will gain in freshness if worked out anew each year. Great insistence should be laid upon the laboratory and outdoor work, and all knowledge should be derived from the study of actual specimens. Mere text-book learning in the training college is like poison at the fountain-head.

8. *Voluntary Help.*

Those who are not naturalists by hobby may do much to encourage children by giving their moral support to the simple interests of the way-side. Children may be encouraged to bring curiosities with them to school. Many schools now have a rack of bottles to receive wild flowers picked on the way to school; a slate reserved for Nature notes, where the first scholar who sees a swallow may enter the fact. Pots of growing seedlings may occupy the window-sills. Aquariums are always interesting, and a caterpillar-cage might be tried.

We hesitate to say much about school museums, unless they are to be annually burnt. Their use is in the making, not in the keeping. The course of instruction should be based upon specimens which may be handled freely, and, if necessary, pulled to pieces. But there is great use in a small glass-case where objects brought in by the scholars may be placed at once and where everyone may see them. This would become a 'collection of instructive labels illustrated by appropriate specimens.' But not for long; the contents must be changed more often than a shop-window if interest is to be maintained.

It is just in the country schools, where it is impossible to expect the professional teachers to be specialists in every department at once, that we are most likely to appeal successfully to local residents for help. Leave from the squire to see his new agricultural machinery, a visit to any well-kept flower garden or apiary, help to the pupil-teachers in naming flowers, gifts of books to the school library—any of these would be a great assistance. The difficulties are often personal and real. The teachers know best when the children are interested and when they are tired, and all help extended to the teachers gets through to the children. We want to enlist for the elementary schools the same kind of help from enthusiastic governors, parents, old scholars, and friends which has already done so much for the secondary schools. There is already a Society for

encouraging work in this direction—Secretary, Miss Isabel Fry, 8F Oxford and Cambridge Mansions, N.W.

The Committee of the Corresponding Societies inform us that they are anxious to know how they can best assist Nature study in schools. We suggest for their consideration that there are many members of these societies who are also members of the local education authorities, who could, therefore, do much to bring the best ideals of teaching to the knowledge of their colleagues, and whose personal influence would lubricate any organisation or arrangement that might be necessary to carry out these ideals—for instance, in getting flowers from the parks supplied to the schools. The present is an opportune moment for these societies to bring the advantages of membership to the knowledge of elementary school teachers. They need help in new studies, and the personal good will and companionship of local naturalists will often be useful.

9. Books.

We agree in thinking that books should only play a very subordinate part in teaching intended to bring elementary school children into first-hand contact with facts.

For boys over fourteen, attending a secondary school, ready to do some evening preparation and coming from homes where the cost of books is not too overwhelming, the answer would be different; but the caution that their first introduction should be to the living object is then even more important. We do not suppose that at the ages of twelve to fourteen children can usefully be set to learn lessons from any book which has not previously been explained to them.

A natural history reading-book should never be accepted as Nature study in school. Many a teacher, feeling his own ignorance, may be glad to use such a book to rouse an interest in what he feels himself incompetent to teach. There are many such books which might suitably be put into school libraries or given as prizes.

Interim Report of Sub-Committee on Domestic Work, consisting of Miss COOPER, Miss CLARKE, Miss MAITLAND, Professor ARMSTRONG, Dr. KIMMINS, Dr. SNAPE, Professor SMITHELLS, and Mr. G. FLETCHER (Secretary).

In considering the teaching of domestic economy in primary schools it seems important to bear especially in mind—

- (1) The age and capacities of the scholars;
- (2) The qualification of teachers; and
- (3) The existing accommodation for teaching the subject efficiently.

The necessity for extended and improved teaching of this subject is widely recognised. It is clear that the home is the natural place in which to learn much that pertains to household management, but girls of the working classes at the period when such training could best be acquired are usually engaged in work in the shop or the factory. The opportunity is therefore wanting, and too often when the time comes for marriage the care of a home is undertaken with but the slightest acquaintance with household duties. A whole train of ills will thus be started in an ill-managed home. Although evening classes in domestic economy touch

only a small proportion of the population, much good work may be done in them. Nevertheless the foundations for such training must be laid in the primary school. The main difficulty here, however, arises from the fact that pupils leave at an age too early to have allowed them to obtain an adequate training.

(1) For the sake of convenience we may differentiate between the character of the instruction which may be given to children of different ages. Three suitable periods are (a) from six to eight years, (b) from eight to twelve years, and (c) from twelve years upwards. In the case of children from six to eight little can be done except by precept and example to inculcate habits of personal cleanliness, order, and industry; but these aims should never be lost sight of, and any lesson may serve as the foundation on which to build up such habits.

With children varying from eight to twelve years of age much more may be done, but it is very doubtful whether any systematic instruction in cookery is of much value during this period. Much may, however, be done by means of simple talks and object lessons dealing with personal hygiene and the cleanliness of the home: how to sweep and dust and to wash cups and saucers; how to lay the table; how to knit, sew, and darn; how to prepare vegetables; how to wash and dress younger brothers and sisters—these should form the substance of the instruction given at this stage, and every inducement should be offered to secure the practice in the house of the principles taught in the school. Much useful work may be done at this stage on simple hygiene. The necessity for fresh air and ventilation, the danger of dust and dirt, the way to treat a cut or burn, the avoidance of danger from fire—these and many similar things may be taught and demonstrated.

For the third period—children from twelve years of age and upwards—systematic instruction may be given in domestic economy, and for such teaching special provision is essential. The defect of such teaching hitherto has been that by a too rigid division of the subject into cookery, laundry-work, and needlework the teaching has in many cases become too specialised—too far removed from the needs and home conditions of those receiving it. Such a division is doubtless useful and suitable for older scholars, but for those in attendance at the primary school it seems undesirable to teach one of these branches to the exclusion of others. The inculcation of thrift calls for increased attention, and in this connection it is thought that lessons in cooking might with advantage more generally concern themselves with the preparation of a complete meal for a small family, the cost to be strictly limited to an amount justified by the family earnings. Indeed every such lesson may, and should be, made the occasion for a discussion on the 'household budget' and the relation which the expenditure on the meal bears to the income of the family.

2. The question of the qualification of teachers is all-important. The instruction such as has been described as suitable for children under the age of twelve should preferably be given by one of the regular members of the school staff, and increased attention should be given to so important a subject in the training colleges.

For the more systematic and practical instruction possible for children above the age of twelve a more specialised training—such as is provided in the various training schools of domestic economy—is required by the teacher. Here, however, the same recognition of the importance of thrift and the unity of the subject is necessary.

3. The question of accommodation for the efficient teaching of domestic economy arises in the case of pupils of over twelve years of age. For younger pupils no special provision seems necessary ; but for girls of over twelve special equipment is necessary for the teaching of household operations, such as washing, cooking, and the various duties included under the term 'housewifery.' In the case of large girls' schools the difficulty is not insuperable. In the case of small, and especially of rural, schools the difficulty is considerable, both in respect of accommodation and in the provision of a qualified teacher. In such cases the Committee are of opinion that the provision of centres of instruction is desirable. These centres might be utilised certainly in a large number of districts by a group of small schools whose scholars would be sent at fixed periods to receive instruction by a special teacher. Such centres might also be employed for instruction in manual work for boys in the upper standards of primary schools. The same accommodation might be made available with advantage for evening instruction in these subjects. It is desirable to point out that the equipment for the teaching of domestic economy should approximate as closely as possible to that available in the home. The more closely the arrangements of the domestic economy school can be approximated to those of a well-ordered home the better.

It does not seem desirable to stereotype instruction by imposing a definite and detailed syllabus ; but some guide should be afforded teachers, especially in respect of pupils between, say, the ages of eight and twelve years. In this connection much valuable information may be obtained from the 16th volume of the 'Special Reports on Educational Subjects' (school training for the home duties of women). Special attention may be directed to the article on 'Housewifery Instruction in State-supported Schools in Belgium.' The teaching of domestic economy in Belgium has received careful attention at the hands of the Government, and attention is drawn to the Ministerial Circular of September 1, 1887, which is translated at page 119 of the volume referred to. The Committee hope it may be possible later to prepare a practical course of domestic subjects in detail.

TRANSACTIONS OF THE SECTIONS.



TRANSACTIONS OF THE SECTIONS.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

PRESIDENT OF THE SECTION.—Principal E. H. GRIFFITHS,
M.A., D.Sc., F.R.S.

THURSDAY, AUGUST 2.

The President delivered the following Address:—

My predecessors in this Chair have in general been able to make communications to the Section conveying the results of investigations of their own, or enunciating some principle which would throw a fresh light on the discoveries of others. Mine is a far less happy lot. During the past four years and a half I have been engaged in administrative duties of such a nature that no time has been available for personal scientific work, and little energy even for the study of the work of others. In these circumstances it might have seemed more fitting if I had refused the honour which the Council of the British Association conferred upon me by the request that I would undertake the arduous duties which fall to the lot of the President of Section A. Nevertheless, after much hesitation, I decided to accept the invitation, in the hope that as a looker-on at the struggle of others, and with the experience of an old participator in the fray, I might be able to communicate some impressions which had possibly escaped the notice of those whose attention was necessarily more directed to some special branch of inquiry.

I trust that these words of apology may to some extent explain the nature of what must appear a fragmentary discourse.

In the interval which has elapsed since the last meeting of the Association we have lost many men whose names were household words within the walls of the physical laboratory. It is here only possible to briefly refer to the labours of a few of those distinguished seekers after Natural Knowledge.

The work of Dr. Sprengel has been by no means an unimportant factor in the advance of our knowledge of radiant energy, *x*-rays, &c., if only on account of the perfection of the apparatus for obtaining high vacua which will ever be associated with his name. The practical effect of his discoveries was considerable, for the business of electric lighting is undoubtedly greatly indebted to his labours. Born in 1834, he settled in England at the age of twenty-five. He was elected a Fellow of the Royal Society in 1878, and resided in this country during the remaining years of his life.

The death of Charles Jasper Joly, F.R.S., at the early age of forty-one, robbed mathematics and astronomy of one of their most devoted disciples. His 'Manual of Quaternions' is well known, and those acquainted with his astronomical work are confident that, had his life been spared, he would, as Astronomer Royal of Ireland, have added lustre to an office held by many distinguished predecessors.

Samuel Pierpont Langley was born in 1834. In 1866 he became Director of the Alleghany Observatory at Pittsburg. His first work was the institution of a uniform system of time from the Atlantic seaboard to the Great Lakes. This, the first successful attempt to introduce uniformity of time over a large area, was subsequently widely imitated. In 1880 he invented the bolometer, and thus

opened out a large new field of investigation into the invisible rays of long wave-length proceeding from heated bodies. He analysed in minute detail the lunar heat spectrum, and, more recently, he conducted an inquiry into the nature of the radiations emitted by the glow-worm. In 1881 he conducted his researches into the solar heat of the earth's atmosphere. In 1887 he became Secretary to the Smithsonian Institution. The result of twenty years' labour is to be found in the accurate determination, by temperature alone, of over seven hundred lines in the invisible red spectrum, lines which are fixed with an average probable error of about one second of arc. In 1891 he published his experiments in aëro-dynamics, in 1893 'The Internal Work of the Wind,' and in 1896 he demonstrated by actual experiment that a body nearly a thousand times heavier than air can be driven through and sustained by it. His published works show great literary charm. He especially excelled in the presentation of abstruse subjects in simple and non-technical language. This is, perhaps, hardly the occasion to refer to his social qualities. Those who had the privilege of his acquaintance, however, can best testify to his quickness of insight, his intense sympathy, especially with the young, and the impression of capability which he produced upon all with whom he came in contact.

The tragic death of Professor Curie was felt as a calamity, not only by those closely interested in the march of scientific discovery, but also by those who had but a superficial knowledge of his work. A teacher for more than twenty years, he was nevertheless enabled by his enthusiasm and energy to perform those researches which will ever be connected with his name and that of his wife. So entirely has public attention been attracted to their joint work on the separation of the compounds of radium and their properties that we are apt to overlook other great services he rendered to science. His paper on 'The Effect of Temperature on the Magnetic Properties of Bodies' led to the discovery of the law that for feebly magnetic substances the coefficient of magnetism varies inversely as the absolute temperature. He also pointed out that the magnetisation of diamagnetic substances appeared to be independent of the temperature and physical state, indicating diamagnetism as an atomic property.

It is pleasing to reflect that the importance of his discoveries received immediate recognition. It was but three years before his death that he announced to the French Academy the discovery of the new element, and in the same year he and Mme. Curie received the Davy Medal of the Royal Society and the Nobel Prize; and in July of last year he was elected to the French Académie des Sciences. He was one of the most modest and retiring of men, and this honour came to him unsought; his name will ever be remembered as one of the most notable of that brilliant band of workers who have within recent years so greatly extended the domain of physics by the discovery of radio-activity.

A quarter of a century has passed since this Section, meeting in this city of York, had the privilege of listening to a Presidential address by the pioneer of natural knowledge whom we now know as Lord Kelvin, and it may possibly be a not unprofitable task to review briefly a few of the advances which must render the interval a memorable one in the annals of science.

Lord Kelvin summarised the stores of energy from which mechanical effects can be drawn by man as follows:—

- (1) The food of animals.
- (2) Natural heat.
- (3) Solid matter found in elevated positions.
- (4) The natural motions of water and air.
- (5) Natural combustibles.
- (6) Artificial combustibles.

The twenty-five years which have since elapsed have not made it possible to extend this list. It is true that within the last few years the discoveries connected with radio-activity have enormously increased our estimate of the stores of energy surrounding us, but so far these additional stores cannot be regarded by us as

stores from which 'mechanical effects may be drawn by man.' It is possible that in the ingenious radium clock which we owe to Mr. Strutt we have a source of mechanical energy unsuspected in 1881, but, at all events, regarded from a commercial standpoint, it can hardly be considered as 'available by man.' Nevertheless, there is a sense in which it may be said that we are profiting by atomic energy, for we are no longer bound to limit our estimate of the energy due to the radiant heat of the sun and the internal heat of the earth by previously known dynamical considerations, and, in consequence, our opinions with regard to the limit of the ages which the physicist could allot to the evolutionist have undergone profound modification.

I here wish to draw attention to some of the conclusions to which we are led by the work of Mr. Strutt.

Assuming the earth to be in thermal equilibrium, then, even if the whole of this interior heat be due to radium alone, the mean quantity per cubic centimetre cannot much exceed 1.75×10^{-13} gramme. The conclusions of Rutherford, based on somewhat different values for the constants involved, give an equivalent of 1.52×10^{-13} . Now Strutt has found that the poorest igneous rock examined by him, namely, Greenland basalt, contains more than ten times this quantity, and an average rock fifty or sixty times the amount. The assumption that the earth is cooling only aggravates the difficulty, and facts appear to tell against the theory that it is getting hotter. Also, we must take into consideration the heat due to the existence of uranium, thorium, &c.

We appear, therefore, to be driven to one of two assumptions: either (a) that the rate of heat production by radium diminishes as we approach the centre of the earth; or (b) that the interior of the earth differs markedly in constitution from the exterior crust.

It is true that Mr. Makower has shown that there is a slight change of activity in one of the radium products about the temperature of 1200° C., and it is very desirable that this inquiry should be pushed to much higher limits. At the same time, it appears evident that but a very slight change in activity takes place at temperatures below 1500° C.

Now Mr. Strutt has shown, arguing from known data, that the maximum temperature at the bottom of a crust of about forty-five miles in thickness, must be in the neighbourhood of 1530° C., although some amount of uncertainty is necessarily induced by our want of knowledge of the conductivity of rock at high temperatures. Anyhow, it is probable that at the depth indicated the temperature does not exceed the melting-point of platinum. Such a crust would contain about one-thirtieth of the earth's volume, and if throughout it the radium heat energy were of the average of that exhibited by many samples examined by Strutt, the temperature of the earth could be maintained until our stores of uranium suffered sensible depletion. Such an assumption would lead to the conclusion that the whole of the central portion of the earth consists of non-radio-active substances at an approximate uniform temperature somewhat below the melting-point of platinum. A brief summary of the evidence previously at our disposal may not be out of place.

In the first edition (1867) of Thomson and Tait's 'Natural Philosophy' we find the tidal evidence summarised as follows: 'It seems certain, therefore, that the tidal effective rigidity of the earth must be greater than that of glass.'

In the 1883 edition of the same work a discussion of the question by Professor George Darwin is given. He states: 'On the whole we may fairly conclude, whilst there is some evidence of a tidal yielding of the earth's mass, that yielding is certainly small, and that the effective rigidity is at least as great as steel.'

In a later paper¹ Darwin pointed out that this conclusion was based on the assumption that oceanic tides would have their equilibrium value, and that the validity of this assumption was open to doubt. Nevertheless, the evidence clearly indicated a high degree of effective rigidity.

Hough² discussed the variation of latitude, and, after correcting a small mistake of Newcomb's (who was the first to suggest the explanation), found

¹ *Proc. Roy. Soc.*, 1885.

² *Phil. Trans.*, A, 1895, 1896.

the prolongation of the Eulerian Nutation from 305 to 430 days as indicating an effective rigidity of the earth about equal to that of steel. Wiechert,¹ of Göttingen, found that the mean density, ellipticity, and precessional constant were consistent with the hypothesis of homogeneous core with lighter surface layer.

Mr. R. D. Oldham,² in a paper on the 'Propagation of Earthquake Waves,' came to the conclusion that the evidence pointed to a central metallic core, and to the existence of marked differences in the physical constants of the core and the surrounding crust. He, however, assigned a comparatively small radius to this core, viz., about 0·55 that of the earth.

I will now call your attention to the light thrown on this subject by the recent investigations of Professor Milne. The difference in the rate of propagation of earthquake waves through the earth's interior and through the crust has led him to the conclusion that the material below a depth approximating to thirty miles is of a uniform nature, and that the change in physical constitution is abrupt at some such depth as that indicated. He writes as follows:—

'For chords which lie within a depth of thirty miles the recorded speeds do not exceed those which we should expect for waves of compression in rocky material. This, therefore, is a maximum depth at which we should look for materials having similar physical properties to those we see on the earth's surface; beneath this limit the materials of the outer part of this planet appear rapidly to merge into a fairly homogeneous nucleus with a high rigidity.'

In the 'Transactions of the Royal Society for 1905' will be found a paper by Lieut.-Col. S. G. Burrard on 'The Intensity of the Force of Gravity in India.' Colonel Burrard writes as follows:—'Geodetical observations have shown that the density of the earth's crust is variable, but they have not given any positive indications of the depths to which these observed variations extend. All calculations of the depths of subterranean variations in density and of the mountain compensation have, therefore, to be based on arbitrary assumptions of depth. The fact that the plumb-line seems generally to respond readily to the results given by the pendulum perhaps justifies the inference that the observed variations in the density of the earth's crust are not deep-seated. If an abnormal amount of matter exists in the crust near the surface, it will exercise direct effects upon plumb-lines and pendulums in the vicinity, but if it lies at a great depth its effects, especially on plumb-lines, will be less perceptible. . . . I have taken several instances of abnormal pendulum results from table, and have found in each case direct response from the plumb-lines at neighbouring stations. This conformity could hardly ensue if the variations in density extended to greater depths than thirty or forty miles. Our results do not justify us in asserting that no deep-seated variations in density exist, but they do justify the belief that the variations in density which have been discovered are apparently superficial.'

It is interesting to notice the agreement between results drawn from such dissimilar sources. On the one hand we have had to deal with effects produced by almost inconceivably small particles travelling with immense velocity; on the other, with effects dependent upon the behaviour of 'the huge terrestrial globe.' That travellers starting from such opposite extremes should arrive at a common destination is in itself a striking example of the scope and accuracy of the work undertaken by investigators in physical science.

It is possible that the evidence from each source, considered independently, might be regarded as inadequate, but the cumulative effect is sufficiently strong to justify the belief that some marked physical change in the constitution occurs at a depth of some thirty to fifty miles.

At all events, we have indications that, with the exception of a comparatively thin crust, the earth consists of a non-radio-active substance with a rigidity approaching that of steel, with an average temperature in the neighbourhood of 1500° C., and a density at that temperature of about 5·6 C.

¹ *Trans. Roy. Soc. Göttingen*, 197.

² *Phil. Trans.*, 1900.

An interesting question awaiting solution is the probable constitution of this core.

The above is but an example of the many fascinating problems upon which fresh light has been thrown by the revelations of recent discoveries in radio-activity, and the temptation to dwell on such themes is correspondingly great; but I feel that such a task should be committed to hands more capable than mine.

Fortunately, in the discussions which will take place during our meeting ample opportunity will be afforded those entitled to speak with authority. Nevertheless, there are one or two further aspects of the matter which I will venture to touch upon, although but an onlooker. I would, first of all, urge the importance of a study of what may be termed the natural history of the elements. We require more information as to their comparative proportions in different localities. The fact that, given the amount of uranium in a sample of native rock, we can predict with certainty the amount of radium contained in the same specimen is of startling significance.

The natural law which governs the proportions of these two substances may have a far wider reaching scope than we at present suspect. Nature appears to present to us a grouping which would not naturally have occurred to the mind of the chemist; lead and silver, copper and gold, and, again, platinum and iridium, seem invariably to be introduced to us by Nature as if bearing to each other some kind of blood relationship.

The facts we already possess seem dimly to indicate some close relation between elements which we have hitherto considered as outside the bounds of consanguinity, and for a fuller knowledge of this important branch of natural history we require the assistance of the practical engineer, the geologist, the metallurgist, and the chemist.

Many of the results arrived at by the investigators into the phenomena of radio-activity can apparently only be verified by the lapse of considerable intervals of time. It is probable, for example, that we can estimate with some degree of accuracy the time required for the dissolution of half a given mass of uranium or radium, but the complete verification of our inferences must probably be left to a future generation. If we accept this view, it is our duty to provide our successors with data on which their conclusions may be based. If, for example, carefully determined masses of the more radio-active substances could be placed in such circumstances as to remain untouched until the meeting of this Association some hundred years hence, our successors, who would doubtless be equipped with apparatus of research more accurate and more sensitive than any in our possession, would at all events be placed in a position to establish by direct methods the accuracy of inferences based upon the experimental data now at our disposal. This task is one which, it appears to me, might well be undertaken by Section A, and I trust that this suggestion may be held worthy of some consideration.

It appears probable that one gramme of radium diminishes in weight by about half a milligramme per annum; hence, if the funds of this Society admitted of the imprisonment of some definite mass of radium, our successors a hundred years hence would, even if they possessed only the apparatus now at our disposal, be able to determine its loss with sufficient accuracy to enable them to verify the truth of the conclusions arrived at by the physicist of to-day, while the investigation of the radio-activity of the residue would possibly throw light on many problems now awaiting solution.

It would appear that if we made a similar imprisonment of uranium, a like degree of accuracy would not be attainable until after the lapse of half a million years, and I am afraid that our interest in the work of our successors cannot be expected to cover so long a period. Nevertheless, it is probable that the presence of the products of decomposition could easily be detected after the lapse of a comparatively short interval of time.

The experiment might well be extended so as to include examples of all the elements capable of such treatment; and with each prisoner should be placed a full record of its physical constants, such as mass, density, electrical conductivity,

specific heat, &c., with a clear indication of what is believed to be the probable accuracy of such determination.

During the past twenty-five years much thought has been devoted to the accurate determination of certain physical constants. This is very apparent in the case of one of the most important—namely, that commonly termed the ‘mechanical equivalent of heat,’ or, as I prefer to define it, the ‘thermal equivalent of energy.’ When Lord Kelvin addressed you in 1882, I think it probable that he would have indicated the value obtained by Joule—viz., 772.6 foot-pounds—at Manchester, as the quantity of work required to raise the temperature of one pound of water through 1° F. at 62° F. It is true that the results of Rowland’s classical investigation were published in 1880 and 1881, but the discrepancy between his conclusions and those of Regnault regarding the change in the specific heat of water at temperatures between 0° C. and 30° C. introduced an element of uncertainty.

As a consequence of this discrepancy much experimental work on the subject has been performed in the last quarter of a century, and I think it may be said without hesitation that the value of this important constant is now ascertained with an accuracy of about one part in 2,000. The amount of labour which has been employed in the determination of this thermal constant is extraordinary, and, as I have pointed out elsewhere, it well illustrates the cosmopolitan character of scientific investigation.

I have given reasons¹ for specially selecting for consideration the determinations of Rowland, of Bartoli and Stracciati, of Ludin, of Callendar and Barnes, of Schuster and Gannon, and I have ventured to add my own. Thus Baltimore, Pisa, Zurich, Montreal, Manchester, and Cambridge have all contributed to the solution of the problem, and we may now with some certainty say that 777.7 foot-pounds at Greenwich are very closely the equivalent of the amount of heat required to raise 1 lb. of water through 1° on the hydrogen scale at 63°·5 F.

It may possibly appear that the result just quoted is a somewhat poor return for the expenditure of so much thought and labour. I would call attention, therefore, to the fact that the value of this equivalent is dependent on the measurements of many other natural constants; hence any agreement between the results obtained by the observations of Rowland and some of the other observers I have mentioned would only be possible in the absence of errors of appreciable magnitude in the determinations of mass, of change of temperature, and of electrical resistance and current. Certain discrepancies have led to the discovery of hitherto unsuspected cause of inaccuracy, especially in the determination of temperature, and thus the inquiry has rendered valuable service in many branches of physical inquiry.

For example, so far back as 1893 I ventured upon a prophecy that the value assigned to the E.M.F. of a Clarke’s cell was somewhat too high, and that it was possible that 1.4328 represents more truly the potential difference of a Clarke’s cell at 15° C. than the ordinarily accepted value of 1.4342. In the report of the Electrical Standards Committee for 1897 will be found a discussion of this matter, and one of the consequences of the deliberations of that Committee is to be seen in the ampère balance now standing in the National Physical Laboratory.

The results of the observations obtained by this instrument will, I believe, shortly be published by Professor Ayrton and Mr. Mather, but I am at liberty to state that, so far as the observations have been reduced, they point to the conclusion that the prophecy to which I have referred is closely fulfilled. We may say, therefore, with some confidence that the values of those units which form the basis of our system of electrical measurement are not only practically determined with a high degree of accuracy, but that also our measurements of temperature and of energy are placed on a satisfactory footing.

The last few years have been fruitful in revelations which not only profoundly affect the views of students of science, but also are of such a nature as to catch the eye of the public. In some cases the applications of these discoveries to the purposes of mankind have been evident and immediate. Every well-equipped

¹ Griffiths, *The Thermal Measurement of Energy*.

hospital possesses apparatus for the production of Röntgen rays, and I suppose that every bluejacket in the Navy has some degree of acquaintance with those applications of science which have resulted from the discovery of Herzian waves.

The ambition of the student is naturally fired by such examples, and there is a possible danger that the plodding but absolutely necessary work of accurate measurement may suffer by neglect. I therefore venture to repeat the well-established axiom that our advance in scientific knowledge is a function of accurate measurement, and that the student who devotes his energy to the determination of some physical constant is probably giving a 'point of departure' to the pioneer. For it must ever be remembered that to the scientific investigator the rule of three has ceased to hold any significance.

When Lord Rayleigh discovered that the mean weight per litre under standard conditions of chemical nitrogen was 1.251, and that of atmospheric nitrogen was 1.257, the believer in the rule of three would have been unlikely to suspect that this difference of .006 would supply the clue which led Lord Rayleigh and Sir W. Ramsay to the discovery of a new element, a discovery which in its turn led to others of possibly even greater importance. For all we know the next decimal place in any hitherto accepted value may afford another example of the truth of the statement that a part may be greater than the whole.

At the time when Lord Kelvin delivered the Address to which I have already referred the truth of the second law of thermodynamics was probably not so generally accepted as is the case at the present time. Each apparent example of violation of that law has on closer examination proved to be additional evidence of its validity. We seem unable to find those 'sorting demons' of Maxwell's whose existence appears necessary for its violation.

Mr. Campbell recently expressed doubts as to the application of thermodynamic considerations to osmotics. He contended that the errors in the determination of osmotic pressure were greater than those which could be attributed to experimental sources. Now, the theoretical relation between osmotic pressure and the freezing-point is based directly on thermodynamic considerations, and it was because I entertained a belief that the most direct evidence of this much-debated matter could be obtained from the observation of the freezing-point of a very dilute solution that I embarked on a series of somewhat elaborate experiments during the years 1897 to 1901. My removal from Cambridge and the death of my assistant, Mr. C. Green, compelled me to leave that inquiry in an unfinished condition. Nevertheless, I had investigated the depression of the freezing-point in certain solutions varying in strength from 0.0003 to 0.025 gm.-molecule per litre.

Subsequently to my departure from Cambridge Mr. Bedford re-erected the apparatus in another building. After having surmounted great difficulties, he repeated many of my experiments, and he informs me that the numbers he has so far obtained are in almost entire agreement with those previously obtained by me. The molecular depression in the case of cane sugar I found to be 1.858, of potassium chloride 3.720, and I understand that Mr. Bedford's experiments agree with these results with a discrepancy of less than 1 part in 1000. The most probable number obtained from theoretical considerations would be in the former case 1.857, in the latter 3.714. As Mr. Whetham has pointed out, unless there is some balancing of opposite errors of a very improbable nature, it is difficult to imagine a more direct vindication of the application of thermodynamic considerations to the phenomena of solution. I may add that I also examined correspondingly dilute solutions of sodium chloride, barium chloride, sulphuric acid, potassium bichromate, magnesium chloride, and potassium iodide; but, owing to the circumstances to which I have referred, I was unable to repeat these experiments in such a manner as to enable me to attach great importance to the resulting figures. Nevertheless, I obtained values which strengthened the conclusions to which I was led by the more exhaustive examination of the dilute solutions of sugar and potassium chloride.

So far back as the Liverpool Meeting of this Association I expressed a hope that the experimental difficulties of the direct measurement of osmotic pressures

would be overcome, as such direct measurement would afford the most useful data by means of which to obtain further light on the much-vexed question of the nature of solutions. I remember, also, that it was the general opinion of those who had given attention to this matter that the experimental difficulties were insuperable.

I am glad, therefore, to have this opportunity of stating my high appreciation of the manner in which Lord Berkeley and Mr. Hartley have grappled with the difficulties of this investigation. They have proved that the osmotic pressure obtained by direct measurement agrees with that derived from vapour-pressure observations to within less than 5 per cent.¹ This agreement is of great importance, as it diminishes our doubts as to the extent to which the imperfections of semi-permeable membranes may affect the validity of results dependent upon their behaviour, and points to the possibility of determining the osmotic pressures of concentrated solutions by measurement of their vapour pressures.

I trust it will not be thought out of place if I here refer to the interesting correspondence which has recently appeared in 'Nature' on the thermodynamic theory of osmotic pressure, and the allied, but by no means identical, problem of the difference between electrolytic and non-electrolytic solutions.

On the one side we have Professor Armstrong, whose chief desire appears to be the vindication of the moral character of what he terms 'the poor molecule'; and Mr. Campbell, whose doubts concerning the second law of thermodynamics are closely connected with a lurking belief in the existence of Maxwell's 'sorting demons'; and by way of reserves we have Professor Kahlenberg, who contends that 'thermodynamic reasoning cannot be applied to actual osmotic processes' on account of the 'selective action of the membrane' and 'insists that the formation of crystals from a solution or the concentration of a solution by evaporation are not osmotic processes.'

On the other hand we have Mr. Whetham, who, I confess, seems to me to be capable of holding his own without need of reinforcements. He has pointed out that confusion has arisen from the use of the term 'osmotic pressure' to denote the actual pressure experimentally realised in certain conditions, as well as the ideal pressure required in thermodynamic theory. With regard to the theory of electrolytic dissociation, Mr. Whetham shows that the fact that the velocities of the ions are constant in dilute solutions and decrease slowly with increasing concentration, while the conductivity of a dilute solution is at most proportional to the first power of the concentration, appears irreconcilable with any assumption as to the existence of the active part of an electrolyte in the form of combined molecules when in solution. I would here join with Mr. Whetham in the request that those who oppose the theory of ionic dissociation would state their views as to the mechanism of electrolysis, and their reasons for supposing that the application of the principles of thermodynamics to the phenomena of solution is unjustifiable.

Professor Armstrong remarks that it is unfair to 'cloak the inquiry by restricting it to thermodynamic reasoning, a favourite manœuvre with the mathematically minded.' He adds that such a course may satisfy the physicist, but 'is repulsive to the chemist.'

The inquiry, 'Why is the application of thermodynamic reasoning repulsive to the chemist?' naturally suggests itself. I confess that at one time I regarded the extreme advocates of the theory of ionic dissociation with a certain amount of suspicion, but I think that most of those who have studied the evidence now at our disposal, or who have been engaged in experimental investigation into this interesting branch of physics, cannot fail to agree with Mr. Whetham that, as

¹ Concentration.	Direct O.P. at 0° C.	O.P. deduced from vapour pressure at 0° C.
540 grains per lit. solution	• • 67.5	69.4
660 " " "	• • 100.8	101.9
750 " " "	• • 133.7	136.0

regards the fundamental conceptions of the theory, 'the cumulative evidence seems overpowering.' At all events, we may consider that the application to the phenomena of solution of reasoning based on thermodynamic considerations is justifiable, until we are presented with stronger arguments than those based on the repulsiveness to certain chemists of the conclusions to which it leads, or the doubt it throws upon the activities of Maxwell's demons and the selective action of semi-permeable membranes.

I will now trespass upon your forbearance and pass from the consideration of such special departments of natural science as usually engage the attention of members of this Section to some more general considerations, which naturally arise in any comparison of our knowledge of to-day with that which we possessed when we last met in this city.

It will, I think, generally be admitted that during the last twenty-five years the increase in our 'natural knowledge' has been greater than in any previous quarter of a century.

Day by day we are adding new facts to our storehouse of information, until it has now become impossible for the individual to have more than a superficial knowledge of the contents of the building. And although this accumulation is one which we may well regard with satisfaction, it necessarily gives rise to difficulties unfelt by our predecessors.

I venture to indicate one of such difficulties, one which has been brought home to me both by my experience as an examiner and by the fact that during the past few years I have had to preside over many meetings of examiners, and to mark the effect of examinations on the teaching in our universities.

We now expect a student to acquire in a three years' course a far greater amount of information than was considered necessary, say, twenty-five years ago. The attention both of the teacher and of the taught is naturally directed to those extremities of the branches of science in which the growth has been most marked in recent years, and I venture to think that there is in consequence some danger of our neglecting the roots of the whole matter. Compare, for example, a Final paper in chemistry in any one of our universities with its predecessor of a quarter of a century ago.

The enormous advance of organic chemistry has necessarily reacted on the examinations, and thus the student is unable to devote an adequate proportion of his time and attention to the foundations of the subject. The same remark applies in the domain of physics. There is a danger, therefore, of our educational edifice becoming top-heavy.

I have heard complaints, on the one hand, from the examiners that while the candidates frequently exhibit considerable knowledge of the most recent scientific developments, they show a lamentable ignorance of the simple phenomena and the principles they illustrate. On the other hand, I have heard from candidates that many of the questions were too simple—that they were concerned with principles and facts to which their attention had not been directed since they first began the study of natural science.

My own experience has been that the simplest questions are those answered in the least effective manner. A candidate unable to give satisfactory illustrations of Newton's Laws will discourse upon the mass of an electron or the nature of the Röntgen rays, and attempt the solution of problems on such subjects as Hertzian waves and electric convection.

I hope that the attention of both examiners and teachers may be directed to the best methods of dealing with what appears to me to be not only a serious but an increasing evil.

To pass from one of the inconveniences which inevitably arise from growth, it is pleasant to dwell upon its more gratifying consequences.

Perhaps one of the most marked characteristics of the progress of science in recent times is the increasing public appreciation of the importance of original investigation and research.

The expansion of the university colleges in number and importance has greatly assisted and quickened this movement.

Twenty-five years ago there were comparatively few laboratories which held out any possibility of research to the English student. True, there were giants in those days, men, as a rule, working under difficulties greater than those encountered by their successors of to-day. The better equipment of our laboratories and the growth in the number and activity of our scientific societies have played no small part in stimulating public interest. Nevertheless, much remains to be done. Those who have read Professor Perry's somewhat pessimistic words on England's neglect of science must admit that, however rapid our progress, the British people have not yet so fully awakened to the national importance of this question as some of our competitors.

The idea that a degree is one of the chief objects of education yet lingers amongst us. The conviction that it is a national duty to seek out and, when found, utilise the latent scientific ability of the rising generation for the purpose of adding to our stores of natural knowledge still needs to be brought home to the 'man in the street.' And here I would venture to indicate my personal belief in the necessity of more free communication between the laboratory and the marketplace. It is possible that the language of science is becoming too technical, and that the difficulties with which scientific inquirers have been faced in past times have tended to habits of exclusiveness. For example, complaints are frequent that our manufacturers are less alert in grasping the practical applications of scientific discovery than their competitors in Germany and the United States. I confess, however, that it seems to me possible that the fault is not altogether on the side of the manufacturers. We want missionaries to preach the doctrine that one of the greatest of national assets is scientific discovery. If we can convince the men of business of this country that there are few more profitable investments than the encouragement of research, our difficulties in this matter will be at an end.

It is my lot to serve on the education committees of three county councils, and I have been much struck by the readiness of the members of those bodies to extend such encouragement whenever it has been possible to convince them that the results may conduce to the prosperity, the comfort and the safety of the community.

It has also been my privilege to address meetings of the men who work in the coalfields of South Wales. I have attempted to direct their attention to the advantages which they have derived from the labours of those who have endeavoured to probe the secrets of Nature in the laboratory; I have tried to show how discoveries based on the researches of Humphry Davy, Faraday, Joule, for example, have not only diminished the dangers to which miners are exposed, but have also, by increasing the demands upon our stores of energy, given employment to thousands of their fellow-workers.

My experiences lead me to the belief that these men are ready to support the action of their representatives in extending support and encouragement to all efforts to assist the advance of scientific discovery.

It is possible that in dwelling on this matter I am trespassing on your forbearance, but I cannot resist this opportunity of pleading for the extension of your sympathies beyond the walls of the laboratory. The old toast, 'Here's to science pure and undefiled; may it never do a ha'porth of good to anybody,' may possibly be an excellent one in the laboratory; for, so far as I know, no great scientific principle has ever been established by labours prompted solely by desire for financial gain. Nevertheless, if we wish for the support of our fellow-countrymen, that toast is not one for public dinners. There is no scientific society which is brought into such close contact with the public as is the British Association, and affiliated with that Association are some scores of local scientific societies, containing many thousands of enthusiastic observers and inquirers. If this great organisation were seriously to take up the task of bringing home to the minds of the people of this kingdom the enormous value of the results of scientific inquiry, I believe it might be possible to change the indifference and apathy of our public bodies into active interest and encouragement. If each affiliated society would institute a series of public non-technical lectures, of such a nature as to bring home to the minds of the hearers some comprehension of the results of the work of Faraday, of Wheatstone, of

Pasteur, of Maxwell, of Lister, and of Kelvin, the change in the public attitude would be real, evident, and fruitful.

In conclusion, one is tempted to seek for the underlying cause of the acceleration in the rate of advance of natural knowledge. Is it to be found in the increase in power of the human intellect, or the diversion into one particular channel of activities previously otherwise employed? It is possible that the human intellect has, by the processes of evolution, become more powerful, and that man's ability to decipher the secrets of Nature has thereby increased. I think, however, that it would require a bold advocate to support this thesis. If any such mental evolution has taken place, it is strange that it should be restricted to one particular sphere of activity. Are our poets and authors of to-day greater than Homer, our statesmen than Pericles? Or, passing into the domain of science, can we say with confidence that, in pure power of reasoning, Maxwell was undoubtedly the superior of Archimedes?

I have elsewhere indicated what appears to me to explain the mystery of this acceleration, namely, *the extension of our senses* by mechanical appliances. When we supplement our eyes by the bolometer and the electric coherer, the range of our vision is augmented a thousandfold. By the use of the electroscope and the galvanometer we have extended our senses of sight and touch until we can detect the presence of an electron.

Having realised the imperfection of our faculties, we have called upon Nature in all departments of science to supply our deficiencies, and are thus enabled to walk with confidence where previously all seemed dark.

From the time of Archimedes to that of Bacon we despised Natural Knowledge, while we deified intellect and authority; hence for nearly two thousand years our record was one of retreat rather than advance. When the philosopher left his study and applied his powers of observation to the phenomena of the universe, progress became a reality, and thenceforward the march of discovery has known no backward step. We have therefore every reason to believe that when the Association again visits this ancient city our President will be able to chronicle an increase in Natural Knowledge even greater than that which has been one of the distinguishing characteristics of the last quarter of a century.

The following Papers were read:—

1. *Photographs of the Arc Spectrum of Iron under High Pressures.*
By W. G. DUFFIELD.

Using a pressure-cylinder designed by Dr. Petavel, photographs of the arc spectrum of iron have been taken in air at pressures ranging from 1 to 100 atmospheres. Slides showing the displacement of the lines from their normal positions under high pressures were shown to the Section, and attention was drawn to the behaviour of reversed lines. Under a pressure of 100 atmospheres displacements amounting to one Angström unit had been measured.

2. *Measurements of Osmotic Pressure.* By the Earl of BERKELEY, F.G.S.
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FRIDAY, AUGUST 3.

Discussion on the Evolution of the Elements.
Opened by F. SODDY.—See Reports, p. 121.

The following Papers were read :—

1. *On the Notation and Use of Vectors.*
By Professor O. HENRICI, F.R.S.

2. *The Notation and Use of Vectors.*
By Professor C. G. KNOTT, D.Sc., F.R.S.E.

It is undeniable that Hamilton's Quaternion Calculus embodies the first completely worked out system of vector analysis ever given to the world. In view of the excessive multiplication in recent times of vector notations, a question worthy of consideration is, Do any of these notations excel Hamilton's in brevity, in compactness, in graphic appeal to the eye and sense, in manipulativeness, and in freedom from arbitrary invention of symbols?

It is easy to show from the papers and books of most of the present-day non-quaternionic vector analysts that they have not really studied Hamilton's method at first hand. Had they done so they would have seen that Hamilton's notations are, in a manner familiar in the history of mathematical development, simply short-hand expressions for the statements. Thus Vab is the vector of the product of the vectors a, b ; Sab the scalar of the same product; and so on. These with Hamilton are selective symbols, and pick out parts of the complete product of two, three, four, or any number of vectors. These vector products are amenable to all the ordinary rules of algebra with the exception of the commutative law. This is not the case with the rival systems of vector algebra. For fancied convenience at the start the associative law is disregarded. So long as we keep to products of two vectors the associative law does not come into play; hence for the simpler applications all the systems are practically identical in their modes of attack on any problem. But when products of three or more vectors or vector operators have to be considered it is obvious that the calculus which retains the associative law must have the greater flexibility. Especially is the value of the associative law shown in the use of ∇ , which in all non-quaternionic vector systems is robbed of much of its power and analytical adaptability.

It was the retention of the associative law which compelled Hamilton to identify Sab with *minus* the product of the lengths of the vectors into the cosine of the angle between them. The customary method is to use Hamilton's name, but change the sign. But the change of sign involves far more than appears at first. It compelled Gibbs to make use of a third kind of product in addition to the so-called fundamental ones represented by Hamilton's $-Sab$ and Vab ; and more recently it has compelled Jahneke also to introduce a third, but quite different kind of product of two vectors in order to be able to treat of strains. This is surely a confession of weakness. In the quaternion vector analysis as developed by Hamilton and Tait, the treatment of the strain function grows naturally out of the system.

To compare the merits of notations, take the following expressions in Hamilton's, Gibbs's, and Henrici's notations :—

$$\begin{aligned} V. V a\beta V (V \gamma \delta V \epsilon \rho), & \quad (a \times \beta) \times ((\gamma \times \delta) \times (\epsilon \times \rho)), & \quad [[a\beta][\gamma\delta][\epsilon\rho]] \\ S. V a\beta V \gamma \delta V \epsilon \rho, & \quad (a \times \beta) \cdot ((\gamma \times \delta) \times (\epsilon \times \rho)), & \quad ([a\beta][\gamma\delta][\epsilon\rho]) \\ & \quad \text{or } ((a \times \beta) (\gamma \times \delta) (\epsilon \times \rho)), & \quad \text{or } ([a\beta][\gamma\delta][\epsilon\rho]). \end{aligned}$$

Here, in addition to the six vectors which are common to all, Hamilton uses eight other symbols of operation in the first case and five in the second, Gibbs requires thirteen for the first and thirteen (or eleven) for the second, and Henrici uses ten in the first and ten or eight in the second. Although the cross and dot are the essential symbols in Gibbs's notation, the brackets are absolutely necessary in complex expressions, just as they are, but to a distinctly less extent, in the quaternion notation. There is no doubt that Hamilton's is the more economical; it is in the natural order of the verbal description of each expression; and it is certainly not less graphic than either of the others.

One great advantage of the quaternion notation over all others is that it can be applied at once, without further definitions, to products of more than two vectors. The non-associative vector algebras cannot treat of vector products until the vectors have been grouped in pairs. The two *apparent* exceptions given above are really cases of contracted symbolism.

Heaviside's notation differs from Hamilton's in dropping the S before the scalar of a product and changing the sign; but here also the notation is inapplicable to higher products, because by putting the square of a unit vector equal to +1 Heaviside makes his system also non-associative.

It has been said that the quaternion is not required in physical applications. In a certain sense this may be admitted; and yet in no other vector algebra can finite rotations be treated as they are in the quaternion system by means of the beautiful operator $q () q^{-1}$. But as a matter of strict logic the quaternion product of two or more vectors is always present. Its fundamental properties determine the whole method of the calculus. Certain parts of it come to the front incessantly, just as in ordinary trigonometry the sines and cosines have an analytical importance far exceeding that of the angle or arc.

MONDAY, AUGUST 6.

DEPARTMENT OF PURE MATHEMATICS.

The following Papers were read:—

1. *Expansions in Products of Oscillating Functions.*
By Professor A. C. DIXON, F.R.S.

The problem is to prove the validity of the expansion of a function of two variables, x, y , in the form

$$\Sigma \Lambda \phi(x) \psi(y),$$

where $\phi(x), \psi(y)$ are functions satisfying certain differential equations, $\frac{d^2\phi}{dx^2} = P\phi, \frac{d^2\psi}{dy^2} = Q\psi$. P, Q are functions of x, y respectively, and also linear functions of two parameters, λ, μ . The summation extends over the pairs of values of λ, μ given by such a system of equations as $\phi(a) = \phi(b) = 0 = \psi(a)\psi(b)$, where a, b are the ends of the range of real values over which the expansion is to hold good.

The investigation depends on an expression for $\Sigma \phi(x)\phi(t)\psi(y)\psi(u)$ in the form of a double contour integral.

2. *Anemoids.* By Professor W. H. H. HUDSON, M.A.

An *Anemoid* is the path of a particle of air in a storm on the following hypotheses:—

- (1) The centre (Q) of the storm moves in a straight line.
- (2) The direction of motion of the air particle (P) makes a constant angle ($\frac{1}{2}\pi - \alpha$) with the join of the air particle to the storm-centre.
- (3) The velocity of the storm-centre has a constant ratio (μ) to the velocity of the air-particle.
- (4) The motion is in one plane.

Taking rectangular axes as indicated in the diagram, in which PT, PG are tangent and normal to the Anemoid, we have

$$\frac{d}{ds} \{x + y \tan(\phi - \alpha)\} = \mu$$

For a cyclonic Anemoid, a is the angle of incurvature.

For an anticyclonic Anemoid, change a into $-a$; a then becomes the angle of excurvature.

Make the following substitutions:

$$\begin{aligned} p &= \sin a / \sqrt{(\cos^2 a - \mu^2)}, & -\tan \frac{1}{2} \phi' &= (\cos a - \mu)^{\frac{1}{2}} (\cos a + \mu)^{-\frac{1}{2}} \cot \frac{1}{2} \psi \\ q &= \sin a / \sqrt{(\mu^2 - \cos^2 a)}, & -\tan \frac{1}{2} \phi' &= (\mu - \cos a)^{\frac{1}{2}} (\mu + \cos a)^{-\frac{1}{2}} \coth \frac{1}{2} \chi \\ t &= p\psi = q\chi. \end{aligned}$$

Also suppose that when $\phi = \phi_0, x = h, y = k$.

The equations of the Anemoid are shown to be

$$y/k = f(\phi) / f(\phi_0) \quad (x-h)/k = \frac{F(\phi) - F(\phi_0)}{f(\phi_0)}$$

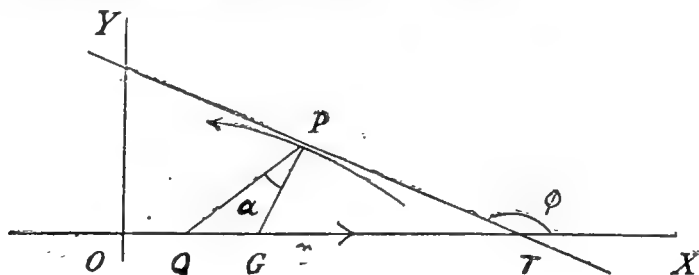
where

$$f(\phi) = -\cos \phi' e^{-t} / (\cos a - \mu \cos \phi')$$

$$F(\phi) = (-\mu + \mu^2 \cos a \cos \phi' + \sin a \sin \phi') e^{-t} \{ (1 - \mu^2) \sin a (\cos a - \mu \cos \phi') \}$$

$p, \psi,$ or $q, \chi,$ being used according as $\mu <$ or $>$ $\cos a$.

When $\mu = \cos a,$ the general equations do not apply.



Turn the axes through an angle a about the point where the air-particle falls into the storm-centre. The equations may be written:

$$x/a = - (Z^2 + 1 - \tan^2 a) e^{-Z} \quad y/a = 2Z \tan a e^{-Z}$$

where

$$Z = 1 - \tan a \cot \frac{1}{2} \phi'$$

The case $\mu = 1$ is also exceptional. In this case let

$$Z = \sin \frac{1}{2} (\phi - 2a) / \sin \frac{1}{2} \phi$$

and suppose that when $Z = Z_0, x = h, y = k$. The equations are

$$\begin{aligned} y/k &= f(Z) / f(Z_0) \\ \sin a (x-h)/k &= \{ F(Z) - F(Z_0) \} / f(Z_0) \end{aligned}$$

where

$$\begin{aligned} f(Z) &= 1/Z - \frac{1}{2} (\cos a) / Z^2 - \frac{1}{2} \cos a \\ F(Z) &= (\cos a) / Z - \frac{1}{4} (\cos 2a) / Z^2 + \frac{1}{2} \log Z \end{aligned}$$

If $\mu = 0,$ the Anemoid is an equiangular spiral, which becomes a circle when $a = 0$.

If $a = 0,$ there is neither incurvature nor excurvature, and the path may be called a *right* Anemoid. The equations are:

$$\begin{aligned} \mu < 1 & \quad (1 - \mu)y/c = -\mu + \cos \psi \\ & \quad (1 - \mu) \sqrt{(1 - \mu^2)} x/c = \mu \psi - \sin \psi \\ \mu = 1 & \quad 9cx^2 = (c - y)(2c + y)^2 \\ \mu > 1 & \quad (\mu - 1)y/c = \mu - \cosh \chi \\ & \quad (\mu - 1) \sqrt{(\mu^2 - 1)} x/c = -\mu \chi + \sinh \chi \end{aligned}$$

assuming that $x = 0$ when $\psi = 0, \chi = 0, y = c$.

If $\alpha = \frac{\pi}{2}$, the Anemoids are curves of pursuit.

The path of P relative to Q is

$$r/c = -e^{-t}(\cos \alpha + \mu \sin \theta)$$

where r, θ are polar co-ordinates referred to the storm-centre as origin, and

$$\begin{aligned} t &= p\psi && \text{when } \mu < \cos \alpha \\ &= -\tan \alpha \cot(\frac{1}{2}\theta + \frac{1}{4}\pi) && \mu = \cos \alpha \\ &= q\psi && \mu > \cos \alpha \\ &= 0 && \mu = 1. \end{aligned}$$

If $\alpha = 0$, the path is a conic section for all values of μ , and if $\mu = 1$, the path is a parabola for all values of α .

The interpretation of the equations shows that Anemoids belong to four classes:

1. Spirals: $\mu < \cos \alpha$. The coils intersect, touch, or fall each within the preceding, according as $\mu > = < \sin \alpha$.
2. Curves with a stop-point: $\mu =$ or $> \cos \alpha$, but $\mu < 1$. The air-particle falls into the storm-centre at the stop-point. It is shown geometrically that the air-particle proceeds thence along the storm-path.
3. Curves with an asymptote: $\mu = 1$. The asymptote is parallel to the storm-path.
4. Loops: $\mu > 1$.

These classes may be further subdivided according to the value of α .

The trajectories traced from observation by Dr. Shaw and Mr. Lempfert present in several cases a considerable resemblance to portions of Anemoids. When the storm-centre moves in a straight line, the air-trajectories may be looked upon as curves derived from Anemoids by supposing μ and α to vary; if μ and α vary very slightly the Anemoids may be regarded as a first approximation to the trajectories.

3. On Residues of Hyper-even Numbers.

By Lieut.-Colonel ALLAN CUNNINGHAM, R.E.

Let $2^{\xi_1} \equiv 1 \pmod{m}$, $2^{\xi_2} \equiv 1 \pmod{\eta_1}$, . . . $2^{\xi_{r+1}} \equiv 1 \pmod{\eta_r}$,
and $\xi_1 = 2^{a_1} \eta_1$, $\xi_2 = 2^{a_2} \eta_2$, . . . $\xi_{r+1} = 2^{a_{r+1}} \eta_{r+1}$

where m, η_1, η_2, \dots are all odd; and ξ_1, ξ_2, \dots are all minima.
Then ξ_1, ξ_2 , &c. are the *Haupt-exponents* of 2 to the moduli m, η_1 , &c. The η diminish at each step, until eventually (for all moduli m alike) $\eta_{r-1} =$ some Fermat's number, $\xi_r = 2^{a_r}$, $\eta_r = 1$, $\xi_{r+1} = 1$. All moduli (m), which have the same ξ_1 , have the same train of ξ_r, η_r .

Let $E_{0,n} = 2^n$, $E_{1,n} = 2^{E_{0,n}}$, . . . $E_{r+1,n} = 2^{E_{r,n}}$.

These are *Hyper-even Numbers*. Let $R_{r,n}$ be the residue of $E_{r,n}$ to any odd modulus m . The residue system of the r th order, i.e., of $E_{r,0}, E_{r,1}, \dots, E_{r,n}$ (with the same r) to mod. m consists of two parts:—

- (1) A non-recurrent part of, say, $h' = h_r + 1$ terms ($R_{r,0}, R_{r,1}, \dots, R_{r,h}$).
- (2) A recurring cycle of, say, k_r terms ($R_{h+1}, R_{h+2}, \dots, R_{h+k}$). Here $k_r = \xi_{r+1}$, and h'_r is the minimum satisfying the inequalities (of which the first two or three usually involve all),

$$h'_r \nless a_r, 2h'_r \nless a_{r-1}, E_{1,h'} \nless a_{r-2} \dots$$

In passing from one system $E_{r,n}$ to one of higher order ($r+x$) the cycle-length ($k_r = \xi_{r+1}$) decreases rapidly with increase of r , until at length the cycle is reduced to a single term ($R_{h+1} = \text{constant}$), the order (r) being found from $h_r = \xi_{r+1} = 1$; also for all higher orders ($r+x$) the cycle is of one term only, and

this constant term has the *same value* for all. The system $E_{r,n}$ of lowest order (r), in which this constant term occurs, has usually a *non-periodic* portion of length (h') found as above. In passing to higher orders ($r+x$) this unique portion decreases in length (h') with increase of x , until at last it vanishes ($h'=0$), and the residue-system of $E_{r+x,n}$ is reduced to the *constant-term* $R_{r+x,n}$ (of same value as already found, $R_{r,h+1}$); and in all higher orders the residue-system consists of this *same constant-term* alone.

Hence, taking the *column* ($E_{r,o}$) of zero degree of the $E_{r,n}$ system, its residue-system $R_{r,o}$ consists of a *non-periodic* part ($R_{0,o}, R_{1,o}, \dots, R_{h,o}$, where $h=h'-1$ (the h' just found), and a constant term $R_{h+1,o}$ = the constant term just found.

All moduli (m) which have the same ξ_1 have the *same period-lengths* h', k_r in their r th order $E_{r,n}$ residue-systems.

Thus all the *specific factors* of (2^r-1) , and also any product thereof, have the *same* ξ_1 , and have the *same train* of ξ_r, η_r , and also the *same period-lengths* h', k_r when used as moduli.

4. *The Different Kinds of Integrals of Partial Differential Equations.*
 By Professor A. R. FORSYTH, Sc.D., F.R.S.

The customary classification of integrals of partial differential equations of the first order is originally due to Lagrange. The different kinds of integrals to which it leads are called *general, complete, and singular* respectively. In the case of a linear equation in two independent variables, taken to be

$$Pp + Qq = R \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad (1)$$

with the usual notation, the singular integral does not exist; and the general integral is regarded as the most important, on account of a proposition which attempts to prove that this general integral is completely comprehensive. To obtain it, we denote by

$$u = u(x, y, z) = \text{constant}, \quad v = v(x, y, z) = \text{constant},$$

two independent integrals of the equations

$$\frac{d.v}{P} = \frac{d.y}{Q} = \frac{d.z}{R} \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad (2)$$

The general integral is then given by $f(u, v) = 0$; and the proposition asserts that, if $\psi = 0$ be any integral of the partial equation, a form of f can be chosen such that $\psi = f(u, v)$.

If this were universally true, undoubtedly the general integral would be completely comprehensive; but it is not true, for the usual proof of the proposition depends upon a fallacy which was, I believe, first noted by Goursat and by Chrystal. Briefly stated, this usual proof is as follows: Because $u = \text{constant}$ and $v = \text{constant}$ are integrals of the equations (2), the relations

$$P \frac{\partial u}{\partial x} + Q \frac{\partial u}{\partial y} + R \frac{\partial u}{\partial z} = 0,$$

$$P \frac{\partial v}{\partial x} + Q \frac{\partial v}{\partial y} + R \frac{\partial v}{\partial z} = 0,$$

are satisfied identically; and because $\psi = 0$ gives an integral of the equation (1), the relation

$$P \frac{\partial \psi}{\partial x} + Q \frac{\partial \psi}{\partial y} + R \frac{\partial \psi}{\partial z} = 0$$

is satisfied. But this last relation is not necessarily satisfied identically; the

hypothesis, that $\psi = 0$ provides an integral of the equation (1), merely requires that the relation shall be satisfied concurrently with $\psi = 0$. Hence the Jacobian

$$J, = J\left(\frac{u, v, \psi}{x, y, z}\right),$$

vanishes; but it only needs to vanish concurrently with $\psi = 0$. If J vanishes identically (and this is the usual latent assumption in the fallacious proof), then undoubtedly some functional relation,

$$F(u, v, \psi) = 0,$$

or, say,

$$\psi = f(u, v),$$

exists among the quantities u, v, ψ ; and the proposition then would hold. When the Jacobian vanishes, not identically but only concurrently with $\psi = 0$, there is no such functional relation; the proposition then does not hold.

Moreover, it will be noticed that the proposition does not make a declaration of a wider result that the equations

$$\psi = 0, f(u, v) = 0,$$

are satisfied simultaneously; it aims at the definite expression of ψ in terms of u and v .

The range of the limitations upon the validity of the result can be indicated by a different line of argument. As $u = \text{constant}$ and $v = \text{constant}$ are two independent integrals of the equations (2), not more than one (at the utmost) of the Jacobians

$$J\left(\frac{u, v}{x, y}\right), J\left(\frac{u, v}{y, z}\right), J\left(\frac{u, v}{z, x}\right)$$

can vanish identically. Suppose that the first of them does not vanish identically—a hypothesis that imposes no condition. Next, let $x = a, y = b, z = c$ be a set of simultaneous values satisfying the equation

$$\psi(x, y, z) = 0,$$

supposed to give an integral of the original partial equation. Usually there will be a considerable choice in the selection of this set of values. If possible, let a set of values a, b, c be chosen, such that u and v are regular functions of x, y, z in the vicinity of a, b, c , and such also that $J\left(\frac{u, v}{x, y}\right)$, which does not vanish identically, does not vanish for those values. This hypothesis does impose conditions. When the hypothesis is justified, the two equations

$$u = u(x, y, z), v = v(x, y, z),$$

can be resolved so as to express x and y in terms of u, v, z in forms

$$x - a = g(z - c, u, v), y - b = h(z - c, u, v),$$

where g and h are regular functions of their arguments.

Now let these values of x and y be substituted in $\psi(x, y, z)$, with a result

$$\psi(x, y, z) = \phi(z, u, v),$$

where the z , that survives explicitly in ϕ and is contained implicitly in u and v is the z of the integral furnished by $\psi = 0$, and therefore by $\phi = 0$. For this integral we have

$$\begin{aligned} \frac{\partial \phi}{\partial z} p + \frac{\partial \phi}{\partial u} \left(\frac{\partial u}{\partial x} + p \frac{\partial u}{\partial z} \right) + \frac{\partial \phi}{\partial v} \left(\frac{\partial v}{\partial x} + p \frac{\partial v}{\partial z} \right) &= 0, \\ \frac{\partial \phi}{\partial z} q + \frac{\partial \phi}{\partial u} \left(\frac{\partial u}{\partial y} + q \frac{\partial u}{\partial z} \right) + \frac{\partial \phi}{\partial v} \left(\frac{\partial v}{\partial y} + q \frac{\partial v}{\partial z} \right) &= 0, \end{aligned}$$

Multiplying these by P and by Q respectively, adding, and noting that the equation $Pp + Qq = R$ is satisfied by the integral in question, we have

$$R \frac{\partial \phi}{\partial z} + \frac{\partial \phi}{\partial u} \left(P \frac{\partial u}{\partial x} + Q \frac{\partial u}{\partial y} + R \frac{\partial u}{\partial z} \right) + \frac{\partial \phi}{\partial v} \left(P \frac{\partial v}{\partial x} + Q \frac{\partial v}{\partial y} + R \frac{\partial v}{\partial z} \right) = 0.$$

The coefficients of $\frac{\partial \phi}{\partial u}$ and $\frac{\partial \phi}{\partial v}$ vanish identically; and thus we have

$$R \frac{\partial \phi}{\partial z} = 0,$$

as a relation which must be satisfied in order that the given partial equation may have an integral given by

$$\phi(z, u, v) = 0.$$

There are three distinct ways in which the relation can be satisfied.

Firstly, the quantity $\frac{\partial \phi}{\partial z}$ may vanish identically. We then know that $\phi(z, u, v)$ does not contain z explicitly. Thus

$$\psi(x, y, z) = \text{a function of } u \text{ and } v \text{ only.}$$

The proposition, that the form of f in the general integral $f(u, v) = 0$ can be chosen so as to give $\psi = f(u, v)$, is true in this case; and a method of determining the form of f is indicated by the course of the analysis. This is the customarily accepted result. Examples are so frequent that none need be adduced here.

Secondly, the quantity $\frac{\partial \phi}{\partial z}$ may vanish, not identically, but only concurrently with $\phi = 0$. In that case $\phi(z, u, v)$ does contain z explicitly; and the proposition, that the form of f in $f(u, v) = 0$ can be chosen so as to make $\psi = f(u, v)$, is not valid. As an example, given by Chrystal, consider the equation

$$\{1 + (z - x - y)^2\}p + q = 2,$$

obviously satisfied by

$$\psi = z - x - y = 0;$$

we can take

$$\begin{aligned} u &= 2y - z, \quad v = y + 2(z - x - y)^2, \\ \psi &= \frac{1}{16}(2v - u - z)^2 = \phi(z, u, v). \end{aligned}$$

The quantity $\frac{\partial \phi}{\partial z}$ vanishes only concurrently with $\phi = 0$; the general integral cannot be specialised so that $f(u, v) = \psi$. In this example, one hypothesis made in the course of the general proof is not justified. All initial values that satisfy $\psi = 0$ constitute a branch-place for v , so that v is not a regular function in the vicinity of those values.

Thirdly, the quantity $\frac{\partial \phi}{\partial z}$ may not vanish at all; in that case the relation can only be satisfied if $R = 0$. Again, the general integral cannot be specialised so that $f(u, v) = \psi$. As an example, consider the equation

$$xp + 2yq = 2 \left(z - \frac{x^2}{y} \right)^2,$$

obviously satisfied by

$$\psi = z - \frac{x^2}{y} = 0;$$

we can take

$$u = \frac{x^2}{y}, \quad v = ye^{-\frac{x^2}{y}},$$

$$\psi = z - u = \phi.$$

The quantity $\frac{\partial \phi}{\partial z}$ is 1, and so does not vanish at all; and R is zero concurrently with $\phi = 0$. In this example also, one hypothesis made in the course of the general proof is not justified; all initial values that satisfy $\psi = 0$ constitute an essential singularity for v , so that v is not a regular function in the vicinity of those values.

In both of these examples it should be noted that not merely is it impossible to specialise the general integral so as to make $\psi = f(u, v)$, but also that the equation $\psi = 0$ is not part of any equation $f(u, v) = 0$.

As a further example, to illustrate the limitations of the hypothesis, consider the equation

$$(z - xy)^2 p + yq = z,$$

obviously satisfied by

$$\psi = z - xy = 0;$$

we can take

$$u = \frac{z}{y}, \quad v = \frac{1}{2}y^2 + \frac{y}{z - xy},$$

$$\psi = \frac{z}{uv - \frac{1}{2}\frac{z^2}{u}} = \phi(z, u, v).$$

The quantity $\frac{\partial \phi}{\partial z}$ does not vanish, either identically or in virtue of $\phi = 0$; and, in this instance, R is not zero. The explanation is that the argument, leading to the relation $R \frac{\partial \phi}{\partial z} = 0$, is based upon a supposition which is not justified; the equations

$$u = u(x, y, z), \quad v = v(x, y, z),$$

cannot be resolved so as to express x and y as regular functions of z, u, v in the vicinity of values that satisfy $\psi = 0$.

Passing from the particular examples and returning to the interrupted argument, we have seen that the necessary relation will be satisfied if $R = 0$, concurrently with $\phi = 0$. But this condition gives no information concerning $\frac{\partial \phi}{\partial z}$; and all that can be declared is that, if $R = 0$ is satisfied concurrently with $\psi = 0$, the proposition as to the specialisation of the general integral is not necessarily valid. The result has been obtained on the supposition that $J\left(\frac{u, v}{x, y}\right)$ does not vanish identically.

Had we proceeded from the supposition that $J\left(\frac{u, v}{y, z}\right)$ does not vanish identically, then the same doubt about the comprehensiveness of the general integral arises for integrals $\psi = 0$ which make $P = 0$; and, similarly, with $J\left(\frac{u, v}{z, x}\right)$, for integrals $\psi = 0$ which make $Q = 0$.

Naturally we may assume that P, Q, R do not vanish together for an integral $\psi = 0$, because the equation would then be satisfied without reference to the derivatives of z . We may neglect as trivial those integrals $\psi = 0$ (if any) of an

equation which make two of the three quantities P, Q, R vanish. There remain those integrals $\psi = 0$ (if any) which make one of the three quantities P, Q, R vanish.

This last possibility has another bearing. During the discussion we have assumed that u and v are regular functions of x, y, z in the vicinity of values which satisfy $\psi = 0$; but when such values make either P or Q or R vanish, the equations

$$\frac{dx}{P} = \frac{dy}{Q} = \frac{dz}{R}$$

do not necessarily possess regular integrals. Further, Cauchy's existence-theorem is silent as to the possession of regular integrals for initial values, which constitute a branch-place or a singularity of P or Q or R.

Summing up the results, we see that *there may be leakage in the comprehensiveness of the general integral $f(u, v) = 0$, so far as concerns a special integral $\psi = 0$, when values of the variables satisfying $\psi = 0$ are such as to make either P or Q or R vanish, or are such as to constitute any deviation from regularity in u or in v , the quantities out of which the general integral is composed.*

Similar remarks apply to linear equations in more than two independent variables, to equations of the first order that are not linear, to equations of the second order having intermediate general integrals, and to equations of order higher than the second. Sufficient has been said to indicate that special integrals can exist which are not included in the general integral, and to hint that the customary classification of integrals of partial equations of various orders requires revision.

DEPARTMENT OF ASTRONOMY AND COSMICAL PHYSICS.

The following Reports and Papers were read:—

1. *Report on the Investigation of the Upper Atmosphere by means of Kites.*—See Reports, p. 138.

2. *Report of the Seismological Committee.*—See Reports, p. 92.

3. *The Irregular Motions of the Earth's Pole: a Preliminary Graphical Analysis of their Cause.* By Major E. H. HILLS, C.M.G., and Professor J. LARMOR, Sec.R.S.

4. *Note on the Effects of Tremors on Astronomical Observations.* By Professor H. H. TURNER, D.Sc., F.R.S.

In his last report the Astronomer Royal drew attention to the fact that the generating station erected by the London County Council half a mile to the north of the Observatory at Greenwich produced disturbing effects on the observations—among others tremors sufficient to shake the Observatory. The effect of such tremors has been little studied recently, but half a century ago, when railways were first being brought near the Observatory, a number of experiments on tremor were made, not only at Greenwich, but elsewhere. An extreme case of disturbance occurred at the 'Armagh Observatory,' where the Ulster railroad approached within 700 yards, and Dr. Robinson wrote a paper in the 'Proceedings of the Royal Irish Academy' (vol. v. p. 287) calling attention to several ways in which tremors disturbed the observations. The best known is, of course, the shaking of the mercury trough with which observations are made by

reflection, and the consequent difficulty in determining the nadir point. But this is by no means the only disturbing effect. The object of the present note is to recall attention specially to a subtle source of error discovered by Dr. Robinson in an exaggerated form, which in some degree probably affects all observations for position. He found that if after the bisection of a star, but before the microscopes were read, a train was heard to pass, the shaking caused a displacement of the instrument, and the record might consequently be erroneous by as much as 4".

In his explanation Dr. Robinson goes into detail, and refers to the slow-motion screw which is used to make the observation. His particular explanation would, therefore, not always be suitable in the case of other instruments which may have no such screw. At Greenwich, for instance, there is no screw connected with the clamp, bisections of the star being made with the telescope micrometer. But it seems probable that a general form can be given to the explanation to suit all instruments. If an instrument be turned from one position into another very different it will not take up its new position all at once, but for a few minutes after it has been set there will be slow, minute changes going on, arising from the yielding to stresses and the giving way of friction. This is no mere theoretical supposition, for such changes have been proved to occur in the case of the Greenwich transit circle by a long series of flexure observations made in 1894. After setting the instrument on one of the collimators, readings were taken both immediately and after an interval of two minutes, and it was found that both circle and telescope had moved in the interval, the former by about 0''·20 and the latter by about double that quantity. Reasons have been given also for thinking that the R—D discordance is definitely related to changes of this kind, which take place soon after the instrument is set.

Now Dr. Robinson remarks that any tremor will hasten such changes. He speaks chiefly of friction, but his remark applies equally well to yielding to stress. Hence any change in the tremors in the neighbourhood of an observatory will probably introduce some systematic changes in the observations of zenith distance.

The changes are of a kind which might be very difficult to explain, for they might occur in spite of the fact that all the other circumstances had been preserved precisely the same. It is to be remarked also that the previous existence of tremors from railways is no safeguard against a totally new interference from those at present threatened. The former would naturally be intermittent; a train passes now and again, and the observation of a particular star may suffer a little in the manner found by Dr. Robinson; but if the engines of the generating station produce continuous tremors all the observations would be affected.

It is impossible to do more than outline this possible source of error here in default of observations of a special kind, but it seems desirable to put on record these suggestions at the present moment.

5. *Spectroscopic Observations of Solar Eclipses.*

By Professor F. W. DYSON, M.A., F.R.S.

6. *Discussion on Radio-activity and the Internal Structure of the Earth.* *Opening remarks by Hon. R. J. STRUTT, F.R.S.*

It has long been supposed that the internal heat of the earth is merely a remnant of the heat generated by contraction of a primæval nebula. This theory appeared until lately the only possible one: it was open, however, to the objection that in that case the time which could have elapsed since the earth was red-hot became very short—much shorter, in fact, than the requirements of geology could easily admit. Some kind of *modus vivendi* had been reached between geologists and physicists on this matter. It may be doubted, however, whether the result of the controversy was really satisfactory to either party. Two years ago the suggestion was made by several writers that there might be enough radium in the earth to account for the internal heat. Rutherford calculated from some

data given by Elster and Geitel that if the earth contained throughout its volume as much radium as a sample of clay examined by them the temperature gradient at the surface would be about accounted for. I have recently examined a large number of rocks, both igneous and sedimentary, and have been led to the conclusion that there is very much more radium in all of them than would be needed to maintain the earth's internal heat if the earth were constituted of rock throughout. From this I conclude that the interior of the globe does not contain radium, and that in all probability its composition is quite different in other respects also from that of surface materials.

My data for the quantity of radium in rock point to a thickness of at most forty-five miles for the earth's rocky crust. Such a thickness of rock would contain amply sufficient radium to maintain the earth's temperature gradient.

Calculation on these premises, on the assumption that the thermal conductivity of rock is not much affected by change of temperature, proves that the internal temperature at the bottom of the crust (forty-five miles down) would be about $1,500^{\circ}$ C. The inside nucleus, heated by the crust of radium-containing material, must be at this uniform temperature throughout, just as a loaf of bread which has been in an oven long enough takes up a steady temperature equal to that of the walls of the oven.

I have found in discussing the subject with scientific friends who are not concerned with the detailed development of radio-activity that one objection is specially felt. It is urged that a gramme of radium diffused through an enormous volume of rock may not develop nearly so much heat as it would do if concentrated.

In answer to this it may be replied that—(1) there is no reasonable doubt that the heat development of radium is intimately associated with its peculiar electrical behaviour. Indeed, according to Rutherford's data, it can be quantitatively accounted for as the kinetic energy of the α particles emitted. The rate of emission of α particles by pitchblende, as measured by ionisation, is exactly what might be expected on the view that the radium atoms contained in the mineral are as energetic as they would be if they were all collected together. (2) Direct measurements made by Pegram on uranium and thorium have shown that these feebly active elements give about the amount of heat which their activity would lead one to expect. I think that these considerations leave no reasonable ground for the objection above mentioned.

Full details of the experiments and calculations here referred to will be found in the Royal Society's 'Proceedings,' A, vol. lxxvii. p. 472.

TUESDAY, AUGUST 7.

DEPARTMENT OF PURE MATHEMATICS.

The following Papers were read:—

1. *Some Notes on Finite Groups.* By HAROLD HILTON.

1. If Cayley's colour-groups are to be of practical value they must be sufficiently simple to appeal readily to the eye. This can often be secured by drawing the diagrams on a surface of suitable class. In particular, diagrams for finite groups of 'genus one' can be drawn on an anchor-ring; and these diagrams give a simple method of determining the order and generating relations of all such groups.

2. A group of order p^{α} whose group of self-conjugate elements is of order p^{β} contains an Abelian sub-group of order $p^{x+\beta}$, if $2\alpha > \beta(2x + \beta - 1)$. This theorem is an extension of one due to Dr. G. A. Miller, and can be proved by the same method.

3. If a, b are elements of the Sylow sub-groups of order p^{α}, q^{β} of a group G of order $p^{\alpha}q^{\beta}r^{\gamma} \dots$, we can readily prove that a and b are permutable if the corresponding elements of the group of co-gredient isomorphisms are permutable.

Hence we get a simple proof of the theorem that a 'special' group is the direct product of prime-power groups.

4. Dr. Miller's results for 'groups of subtraction and division' hold good for groups generated by any two substitutions of the type $x' = (x + b) \div (cx - 1)$.

5. The most convenient form to which successive reflexions in an odd number of planes can be reduced is an inversion about a point followed by a rotation about a line through that point.

2. *On Two New Symmetric Functions.* By Major P. A. MACMAHON, F.R.S.

3. *A Test for the Convergence of Multiple Series.*

By T. J. I'A. BROMWICH, F.R.S.

Cauchy was the first to show that the convergence of the double series of positive terms

$$\sum\sum f(m, n)$$

is deducible from a knowledge of the convergence of the double integral

$$\int\int f(x, y) dx dy$$

and Riemann¹ proved that this double integral might be replaced by a single integral in many cases. Riemann's test has been augmented with a test for divergence by Hurwitz;² and the following test is to some extent connected with those of Riemann and Hurwitz.

If the positive function $f(x, y)$ steadily decreases to zero as x, y increase to infinity, and if $f(x, y)$ has a lower limit $g(\xi)$ and an upper limit $G(\xi)$, when x and y take all positive values for which $x + y = \xi$, then

(i) $\sum\sum f(m, n)$ converges if $\int G(\xi)\xi d\xi$ converges.

(ii) $\sum\sum f(m, n)$ diverges if $\int g(\xi)\xi d\xi$ diverges.

The proof is immediate; for the sum of the terms on a diagonal³ $x + y = n$ is then between $(n + 1)g(n)$ and $(n + 1)G(n)$, because there are $(n + 1)$ terms on the diagonal. Consequently the double series converges with $\sum nG(n)$, that is, with the integral $\int G(\xi)\xi d\xi$; and the double series diverges with $\sum ng(n)$,

that is, with the integral $\int g(\xi)\xi d\xi$.

Example.—Consider the series $\sum\sum f(m^2 + n^2)$, where $f(x)$ steadily decreases to zero as x tends to infinity; it is then evident that we may write

$$g(\xi) = f(\xi^2), \quad G(\xi) = f(\frac{1}{2}\xi^2)$$

because $\xi^2 \geq x^2 + y^2 \geq \frac{1}{2}\xi^2$, if $x + y = \xi$ and x, y are restricted to be positive.

Hence the series $\sum\sum f(m^2 + n^2)$

(i) converges if $\int f(\frac{1}{2}\xi^2)\xi d\xi$ converges;

(ii) diverges if $\int f(\xi^2)\xi d\xi$ diverges.

¹ *Ges. Werke* (1876), p. 452.

² *Math. Annalen*, Bd. 44 (1894), p. 83.

³ The terms are supposed arranged in a square, as usual.

Both results may be summed up in the statement:—

The double series $\Sigma\Sigma f(m^2+n^2)$ converges or diverges with the integral $\int_0^\infty f(x)dx$. (Hurwitz, *l.c.*, p. 87.)

This result can be at once extended to the series $\Sigma\Sigma f(am^2+2bmn+cn^2)$, in which $am^2+2bmn+cn^2$ is restricted to be always positive. Familiar special cases are given by taking $f(x)=x^{-\frac{1}{2}}$ (the double series for Weierstrass's elliptic function $p'u$) or $f(x)=e^{-x}$ (the double theta-functions).

It is easy to extend the test given above to a p -fold series:—

If the positive function $f(x_1, x_2, \dots, x_p)$ steadily decreases to zero as x_1, x_2, \dots, x_p increases to infinity, and if $f(x_1, x_2, \dots, x_p)$ has a lower limit $g(\xi)$ and an upper limit $G(\xi)$ when x_1, x_2, \dots, x_p takes all positive values such that

$$x_1 + x_2 + \dots + x_p = \xi$$

then (i) $\Sigma f(m_1, m_2, \dots, m_p)$ converges if $\int_0^\infty G(\xi)\xi^{p-1}d\xi$ converges;

ii) $\Sigma f(m_1, m_2, \dots, m_p)$ diverges if $\int_0^\infty g(\xi)\xi^{p-1}d\xi$ diverges.

In particular, if the general term takes the form

$$f(a_{11}m_1^2 + 2a_{12}m_1m_2 + \dots)$$

where the quadratic form $\Sigma a_{rs}x_r x_s$ is always positive, and $f(x)$ decreases as x increases, the convergence or divergence of the series depends on that of the integral $\int_0^\infty f(x)x^{p-1}dx$.

4. Many-Valued Functions of Real Variables. By A. R. RICHARDSON.

Some of the general properties of functions of real variables which are many-valued are investigated.

Let $F(p)$ denote the set of values of the function at the point p , and $\phi(p)$ denote the set obtained as the limits of the values of the function at points near p .

Let $\eta(p)$ denote those values of $\phi(p)$ which belong to $F(p)$; $\lambda(p)$ denote those values of $\phi(p)$ which do not belong to $F(p)$.

The difference between the upper and lower limits of $\eta(p)$ is denoted by $\Delta\eta(p)$, and the upper limit to the distance between a point of $\lambda(p)$ from all points of $F(p)$ or $\lambda(p)$ is denoted by $\hat{\omega}(p)$.

Let $\Omega(p)$ be the greater of $\hat{\omega}(p)$ and $\Delta\eta(p)$.

Then many-valued functions may be classified in a similar manner to one-valued functions, and analogous theorems are found to hold.

A more natural classification, however, from one point of view, is to divide the functions into two broad classes, according as $\Omega(p)$ is or is not continuous.

Interpreting this in the language of one-valued functions, these will be classified according as their degree of discontinuity is or is not continuous. It is then found that a large number of the properties of continuous functions are possessed by functions whose degree of discontinuity is continuous.

5. Note on the Semi-convergent Series for $J_n x$.

By Professor ALFRED LODGE, M.A.

The semi-convergent series for the n th Bessel function, viz.,

$$J_n(x) = \sqrt{\frac{2}{\pi x}} \left\{ P \cos \left(x - \frac{\pi}{4} - n \frac{\pi}{2} \right) - Q \sin \left(x - \frac{\pi}{4} - n \frac{\pi}{2} \right) \right\} \quad (1)^2$$

where
$$P = 1 - \frac{(4n^2-1)(4n^2-3^2)}{1 \cdot 2 (8x)^2} + \frac{(4n^2-1^2) \dots (4n^2-7^2)}{1 \cdot 2 \cdot 3 \cdot 4 (8x)^4} - \dots \quad (2)$$

and
$$Q = \frac{4n^2-1^2}{8x} - \frac{(4n^2-1^2)(4n^2-3^2)(4n^2-5^2)}{1 \cdot 2 \cdot 3 \cdot (8x)^3} + \dots \quad (3)$$

can, of course, be condensed into the form

where
$$J_n(x) = \sqrt{\frac{2}{\pi x}} \cdot R \cos \left(x + a - \frac{\pi}{4} - n \frac{\pi}{4} \right) \quad (4)$$

and
$$\left. \begin{aligned} R^2 &= P^2 + Q^2 \\ \cos a &= \frac{P}{R}, \tan a = \frac{Q}{P} \end{aligned} \right\}$$

If values of the function are required for large values of x , beyond those given by existing tables, it seems likely that the above condensed formula would be the most suitable for calculation. The series for R^2 in inverse powers of x is remarkably simple; and, moreover, when x is large it is very nearly constant. The value of a can be obtained from the formula $\cos a = P \div R$, when P and R are known, or it could be independently obtained from a series given in the sequel. These series were discovered by Mr. Walter Gregory (since unhappily deceased) and myself at Coopers Hill many years ago, but were put on one side when Dr. Meissel's tables of $J_0(x)$ and $J_1(x)$ were published, giving these functions up to $x = 15.5$.

It is possible that the series are already known, but I have not seen them elsewhere, and they may be new. At any rate, the proof given in this paper is independent.

The series for R^2 is

$$1 + \frac{1}{2} \cdot \frac{4n^2-1}{(2x)^2} + \frac{1 \cdot 3}{2 \cdot 4} \cdot \frac{(4n^2-1)(4n^2-3^2)}{(2x)^4} + \frac{1 \cdot 3 \cdot 5}{2 \cdot 4 \cdot 6} \cdot \frac{(4n^2-1)(4n^2-3^2)(4n^2-5^2)}{(2x)^6} + \dots \quad (5)$$

It is a remarkably simple series, considering the formulæ for P and Q , whose numerators contain considerably more terms. It can be easily verified to a few terms by actually squaring and adding the series (2) and (3).

It is, like them, a terminated series when n is an odd multiple of $\frac{1}{2}$, and for other values of n it is a semi-convergent series—i.e., the terms decrease for a certain range, and afterwards become alternately positive and negative.

To find the Series for R^2 :—

Let
$$J_n(x) = u \sqrt{\frac{2}{\pi}}$$

and let
$$u = x^{-\frac{1}{2}} S^{\frac{1}{2}} \cos \phi,$$

where
$$S = R^2, \text{ and } \phi = x + a - \frac{\pi}{4} - n \frac{\pi}{2}.$$
 (6)

Then u satisfies the same differential equation as $J_n(x)$, viz.,

$$\frac{d^2u}{dx^2} + \frac{1}{x} \frac{du}{dx} + \left(1 - \frac{n^2}{x^2}\right) u = 0.$$

Taking the relation $x^{\frac{1}{2}}u = S^{\frac{1}{2}} \cos \phi$, and differentiating twice, we obtain

$$x^{\frac{1}{2}} \frac{d^2u}{dx^2} + x^{-\frac{1}{2}} \frac{du}{dx} - \frac{1}{4} x^{-\frac{3}{2}} u$$

$$= \left\{ \frac{1}{2} S^{-\frac{1}{2}} \frac{d^2S}{dx^2} - \frac{1}{4} S^{-\frac{1}{2}} \left(\frac{dS}{dx}\right)^2 - S^{\frac{1}{2}} \left(\frac{d\phi}{dx}\right)^2 \right\} \cos \phi$$

$$- \frac{1}{2} \left\{ S^{-\frac{1}{2}} \frac{dS}{dx} \cdot \frac{d\phi}{dx} + S^{\frac{1}{2}} \frac{d^2\phi}{dx^2} \right\} \sin \phi \quad (7)$$

Now, from the differential equation it follows that the left-hand side of (7)

$$= -x^{\frac{1}{2}} \left\{ 1 - \frac{n^2 - \frac{1}{4}}{x^2} \right\} u = - \left\{ 1 - \frac{n^2 - \frac{1}{4}}{x^2} \right\} S^{\frac{1}{2}} \cos \phi.$$

Hence, equating separately the coefficients of $\cos \phi$ and $\sin \phi$, we find

$$\left\{ 1 - \frac{n^2 - \frac{1}{4}}{x^2} \right\} S^2 + \frac{1}{2} S \frac{d^2 S}{dx^2} - \frac{1}{4} \left(\frac{dS}{dx} \right)^2 = S^2 \left(\frac{d\phi}{dx} \right)^2 \quad . \quad . \quad (8)$$

and

$$\frac{dS}{dx} \cdot \frac{d\phi}{dx} + S \frac{d^2 \phi}{dx^2} = 0 \quad . \quad . \quad . \quad (9)$$

From (9) it follows that $S \frac{d\phi}{dx} = \text{constant} = c$ (say).

Inserting this value in (8), we find

$$\left\{ 1 - \frac{n^2 - \frac{1}{4}}{x^2} \right\} S^2 + \frac{1}{2} S \frac{d^2 S}{dx^2} - \frac{1}{4} \left(\frac{dS}{dx} \right)^2 = c^2 \quad . \quad . \quad (10)$$

Now, since $S = R^2 = P^2 + Q^2$, and is therefore of the form $1 +$ terms containing inverse (even) powers of x , it follows that the value of c^2 is unity.

$$\therefore S \frac{d\phi}{dx} = 1, \text{ i.e. } R^2 \left(1 + \frac{da}{dx} \right) = 1 \quad . \quad . \quad (11)$$

and

$$\left(1 - \frac{n^2 - \frac{1}{4}}{x^2} \right) S^2 + \frac{1}{2} S \frac{d^2 S}{dx^2} - \frac{1}{4} \left(\frac{dS}{dx} \right)^2 = 1 \quad . \quad . \quad (12)$$

This last equation will enable us to expand S .

Differentiating, and writing $n^2 - \frac{1}{4} = 2k$ for brevity, we have, after reduction—

$$\begin{aligned} \frac{2k}{x^3} S + \left(1 - \frac{2k}{x^2} \right) \frac{dS}{dx} + \frac{1}{4} \frac{d^3 S}{dx^3} &= 0, \\ \text{i.e., } 2k \left\{ \frac{S}{x^3} - \frac{1}{x^2} \cdot \frac{dS}{dx} \right\} &= - \frac{dS}{dx} - \frac{1}{4} \frac{d^3 S}{dx^3} \quad . \quad . \quad (13) \end{aligned}$$

Now let $S = 1 + \frac{a_2}{x^2} + \frac{a_4}{x^4} + \dots$. Then (13) becomes

$$2k \left\{ \frac{1}{x^3} + \frac{3a_2}{x^5} + \frac{5a_4}{x^7} + \dots \right\} = \frac{2a_2}{x^3} + \frac{4a_4}{x^5} + \frac{2 \cdot 3a_6}{x^7} + \dots$$

whence

$$\begin{aligned} a_2 &= k, \\ a_4 &= \frac{3}{4} a_2 (2k - 2), \end{aligned}$$

and generally,

$$\begin{aligned} 2ra_{2r} &= -\frac{1}{4} 2r(2r-1)(2r-2)a_{2r-2} + 2(2r-1)ka_{2r-2}, \\ \therefore a_{2r} &= \frac{2r-1}{2r} \left\{ 2k - r(r-1) \right\} a_{2r-2} \\ &= \frac{2r-1}{2r} \left\{ n^2 - \frac{(2r-1)^2}{4} \right\} a_{2r-2}. \end{aligned}$$

Therefore, finally,

$$S = R^2 = 1 + \frac{1}{2} \cdot \frac{4n^2 - 1}{(2x)^2} + \frac{1}{2} \cdot \frac{3}{4} \cdot \frac{(4n^2 - 1)(4n^2 - 3^2)}{(2x)^4} + \dots \quad (14)$$

or, in terms of k , i.e. $\frac{1}{8}(4n^2-1)$,

$$R^2 = 1 + \frac{k}{x^2} + \frac{1 \cdot 3}{1 \cdot 2} \frac{k(k-1)}{x^4} + \frac{1 \cdot 3 \cdot 5}{1 \cdot 2 \cdot 3} \cdot \frac{k(k-1)(k-3)}{x^6} + \dots$$

This establishes the series for R^2 .

To find the series for a , we have by (11)

$$R^2 \left(1 + \frac{da}{dx} \right) = 1.$$

Let

$$1 + \frac{da}{dx} = 1 - \frac{k}{x^2} - \frac{p_4}{x^4} - \frac{p_6}{x^6} - \dots$$

Then

$$\left. \begin{aligned} & \frac{k}{x^2} + \frac{1 \cdot 3}{1 \cdot 2} \cdot \frac{k(k-1)}{x^4} + \frac{1 \cdot 3 \cdot 5}{1 \cdot 2 \cdot 3} \cdot \frac{k(k-1)(k-3)}{x^6} + \dots \\ & - \frac{k}{x^2} - \frac{k^2}{x^4} \\ & - \frac{p_4}{x^4} \\ & - \frac{p_6}{x^6} \end{aligned} \right\} = 0$$

$$\begin{aligned} \therefore p_4 &= -k^2 + \frac{3}{2}k(k-1) = \frac{1}{2}k(k-3), \\ \text{and } p_6, \text{ after reduction,} &= \frac{1}{8}k(k^2 - 14k + 15) \\ p_8 &= \frac{1}{8}k(5k^3 - 190k^2 + 807k - 630). \end{aligned}$$

Inserting these values, and integrating, we find (a being zero when $k=0$)

$$a = \frac{k}{x} + \frac{k(k-3)}{6x^3} + \frac{k(k^2 - 14k + 15)}{10x^5} + \frac{k(5k^3 - 190k^2 + 807k - 630)}{56x^7} + \dots \quad (15)$$

This is not a very nice series for a , but when x is large we may take

$$a = \frac{k}{x} \text{ or, } a = \frac{k}{x} + \frac{k(k-3)}{6x^3}$$

as a sufficient approximation.

Or we may, if we like, calculate P as well as R , and then obtain a from the formula $\cos a = P \div R$.

The interest attaching to the above series for R^2 lies in the fact that when x is fairly large R varies but slowly, and so, similarly, does P .

Hence, if small tables of P and R , or, rather, of $\log P$ and $\log R$, were calculated for different values of x , say, 10, 11, . . . 20, and then 30, 40, . . . 100, and then 100, 200, . . . for different values of n , say at intervals of $\frac{1}{2}$, i.e., for $n = \frac{1}{2}, 1, \frac{3}{2}, \dots$, it would be quite feasible to interpolate in these tables not only for intermediate values of x , but also for intermediate values of n .

A remarkable relation between the values of P and Q for successive values of n differing by unity follows from the formula

$$\frac{2n}{x} J_n = J_{n-1} - J_{n+1} \quad \dots \quad (16)$$

$$\begin{aligned} \text{Thus, } J_n \div \sqrt{\frac{2}{\pi x}} &= P_n \cos \left(x - \frac{\pi}{4} - n \frac{\pi}{2} \right) - Q_n \sin \left(x - \frac{\pi}{4} - n \frac{\pi}{2} \right) \\ &= P_n \cos X - Q_n \sin X, \text{ say.} \end{aligned}$$

$$\therefore J_{n+1} \div \sqrt{\frac{2}{\pi x}} = P_{n+1} \sin X + Q_{n+1} \cos X,$$

$$\text{and } J_{n-1} \div \sqrt{\frac{2}{\pi x}} = -P_{n-1} \sin X - Q_{n-1} \cos X.$$

Hence, inserting these values in (16),

$$Q_{n+1} - Q_{n-1} = \frac{2n}{x} P_n,$$

$$\text{and } P_{n-1} - P_{n+1} = \frac{2n}{x} Q_n.$$

$$\therefore Q_n (Q_{n+1} - Q_{n-1}) = P_n (P_{n-1} - P_{n+1}),$$

$$\text{i.e., } P_n P_{n+1} + Q_n Q_{n+1} = P_n P_{n-1} + Q_n Q_{n-1}.$$

Hence these expressions are independent of n . This result was due to Mr. Gregory.

To see whether they are also independent of x I have evaluated

$$P_{\frac{1}{2}} P_{\frac{3}{2}} + Q_{\frac{1}{2}} Q_{\frac{3}{2}},$$

and find this expression = 1; also the first three terms of $P_0 P_1 + Q_0 Q_1$, leading to the same result.

We may conclude generally (by induction) that

$$P_n P_{n+1} + Q_n Q_{n+1} = 1. \quad . \quad . \quad . \quad (17)$$

Now, since $\tan a_n = Q_n \div P_n$ and $P_n \sec a_n = R_n$, (17) may be written in either of the forms

$$1 + \tan a_n \tan a_{n+1} = \frac{1}{P_n P_{n+1}}$$

or

$$\sec (a_{n+1} - a_n) = R_n R_{n+1} \quad . \quad . \quad . \quad (18)$$

These results may not be very important, but they are very simple and interesting. The reasoning is inductive, and would need to be verified; but this would be easy if short tables of $\log P$ and $\log R$ were calculated as suggested above.

DEPARTMENT OF ASTRONOMY AND COSMICAL PHYSICS.

The following Papers and Reports were read:—

1. *Preliminary Note on the Rainfall Periodogram.*

By Professors A. SCHUSTER, *F.R.S.*, and H. H. TURNER, *F.R.S.*

The rainfall periodograms for Padua (170 years), Greenwich, and Klagenfurt (90 years) show no marked periodicities from twenty-one months to five months. There are, however, features deserving attention near five months in all three periodograms, though the periods are not the same. For Greenwich the period is five months, less one-fifteenth. It is not yet determined whether this is the actual period of the wave or whether the use of monthly means converts a shorter periodicity into this apparent one. A periodicity of 25.00 days is found to exist in the Greenwich rainfall, but the coefficient is too small to give the one of longer period by interference with the month. Other short periods are also indicated. The results will be communicated in detail to the Royal Society.

2. *On the Connection between Disturbed Areas of the Solar Surface and the Solar Corona.* By the Rev. A. L. CORTIE, S.J., F.R.A.S.

The general connection between the state of disturbance of the sun's surface and a particular type of solar corona is well established. The similarity of the photographs of the solar coronæ of the years 1870, 1882, 1893, 1905 is very marked. These were years of maximum solar activity, with many and great outbursts of spots and prominences. Whether the spots or the prominences are the more intimately connected with the streamers which constitute the characteristic forms of the maximum type of corona is open to question. In the Stonyhurst photographs of the corona of 1905 August 30, the streamers seemed in general to mark the regions of prominences rather than those of the sun-spots. Also, the complicated structures of arches with vortex rings in the lower corona were attached to the prominences. The sun-spot zones were marked by some straight bright rays in the south-west quadrant, and by a set of beautiful plumes in the south-east quadrant. In the discussion of the results of the eclipse presented to the Royal Irish Academy it¹ was shown that the area on the sun's surface to which these plumes seemed to converge was situated in the south-east quadrant, at mean latitude, approximately -21° S. The latitude of the largest of the four sun-spots visible on the day of the eclipse was -20° S., and this spot area was removed some 41° from the sun's east limb. On the invisible side of the sun, removed about 51° from the limb, and in latitude -16° S., sufficiently near to the convergence latitude of the plumes, was placed the area that had been the seat of the great February spot of 1905, the greatest seen for thirty years. If the plumes converged behind the visible disc, it was possible that they were connected with the area of disturbance of the February spot; if to an area on the visible hemisphere, they would converge to a position occupied by the largest spot of the day of eclipse, and formerly occupied by a spot visible to the naked eye during July. Since writing the paper for the 'Transactions' of the Royal Irish Academy the life-histories of the spots and faculæ occupying these two regions have been carefully studied from the Stonyhurst drawings. The region of the great February spot was disturbed from January 5, 1905, to July 14, mean longitude 330° , latitude -16° , but after the latter date became quiescent, and remained so during the eclipse. But the region of the July spot, and the spot of the day of eclipse, was disturbed from May 11 to August 30, covering the period of eclipse. Therefore the connection, if any, was between the coronal plumes and this disturbed area. The connection seems probable, and more than a mere coincidence, from the study of a similar region in 1893, which, as shown in the Greenwich photographic results, was intermittently disturbed from March 15 to November 16, and coincided in position (longitude 45° , latitude -8° S.) with a similar structure in the lower solar corona as described by Professor Schæberle in the report of the total solar eclipse of April 16, 1893 ('Contributions from the Lick Observatory,' No. 4, p. 100).

3. *Telescopic Observations of Meteorological Phenomena.*
By Miss C. O. STEVENS.

The writer drew attention to the fact that the 'boiling' definition, so disturbing to progress and accuracy of astronomical observations, is in itself a phenomenon of great interest and value as an index of meteorological conditions. It is better to be studied by means of a projected telescopic image of the sun than by observation of moon, planets, or the stars. By careful analysis the movements of 'boiling' are found to bear a definite relation to the prevailing drift of the atmosphere, both in respect of direction and amplitude of movements. Two distinct elements of distortion are displayed by the drift of any given stratum of atmosphere across the sun's disc. This fact makes it possible to distinguish between over-lying strata (travelling at an angle to one another) even in the

¹ *Trans. Roy. Irish Acad.*, vol. xxxiii, section A, part 1.

absence of visible clouds; for where the direction of drift is tangential to the sun's limb the character of distortion is that of a progressive '*rippling*' along the limb in the direction of the movement of the air, and where the direction of drift is at right angles to the limb of the sun this rippling character of distortion is converted into a '*springing*' in and out of the area of the sun's image. These co-ordinated movements suggest that the superficial surfaces of layers of air are normally waved or '*rippled*,' the troughs and crests of the waves lying in parallel formation at right angles to the direction of their propagation. If this be the case the problem of '*shadow bands*' associated with total solar eclipse may find its solution in waves of this nature being made visible upon the ground conditionally upon the circumstance of limited illumination. The reliability of the writer's method of observation has been proved by comparison of her records with contemporaneous official records of the Royal Meteorological Society. Her paper on the subject, presented to that society in April last, is to be found in the society's '*Quarterly Journal*,' July 1906. The applicability of the method to the study of the drift and conformation of the more inscrutable regions of the air is obvious. It is also to be employed for detecting *variations* in those atmospheric conditions that find their expression in phenomena of *selective* absorption and diffraction of light. Such evidences as have been obtained show a complete accord with established opinions regarding *colours* associated with *sunrise* and *sunset*, in so far as these are typical of weather. They consist of variations in the fringe of colour associated with the telescopic image of the sun and appear to be deserving of attention as a genuine meteorological phenomenon. It was claimed in conclusion that it is pre-eminently to the sun, with its penetrating light and measurable disc, that the meteorologist must turn for news of the highest regions of the atmosphere, and to elucidate, amongst other problems, that of the source of atmospheric electricity, which, granted it is ever generated by friction between cloud-masses, is doubtless generated also by friction between contiguous strata of air, moving as these do in so much the more intimate and effectual contact.

4. *On the Radiation of Heat from the Moon.* By the Earl of ROSSE, K.P., F.R.S.

In this paper, after shortly recapitulating the principal points of a communication to Section A at Cape Town last year, in which the difficulties in the way of advancing the subject in an unfavourable climate and without the co-operation of other workers are stated and dwelt upon, the main particulars of some heat determinations made during the lunar eclipses of 1898 and 1903, which have been lately fully reduced, are given.

As had been anticipated, owing to circumstances adverted to above, these observations are found to be quite inconclusive on the two points on which further information was particularly desired.

The lagging, however, of the decrease and subsequent increase of the heat behind the light was unmistakably detected.

5. *York Rainfall Records and their Possible Indication of Relation to Solar Cycles.* By J. EDMUND CLARK.

Meagre records exist for 1811 to 1824, and unbroken records from 1831. The average rainfall from 1831 to 1900 is 24·766 inches. Decades vary from 23·265 in the fifties to 28·036 in the seventies. The mean for the eighty-nine years is 24·57 inches.

The monthly curve (thirty-days means) ranges from 1·56 inches in March to 2·48 in July, 2·51 in August, 2·17 in September, and, the maximum, 2·54 inches in October.

The September break is peculiar. This month averaged 3·36 inches in the

seventies, the highest mean for any month in any decade. 'Rainy days' give no break in September.

To test for any relation to solar activity the whole-year and monthly falls were taken for the three years nearest each of the six maxima and the six minima between 1831 and 1901. The object of what follows is to get opinions whether there is justification for examining the matter further.

The whole-year fall showed an excess for the eighteen years at maxima of 50 inches over the 425·73 inches of the eighteen years at minima. This is +12 per cent.

Each maximum exceeds the preceding minimum, except in the case of the seventies' minimum.

Nine of the months contributed to this excess. August only is markedly reversed. The eighteen years 21·76 inches (or $-36\frac{1}{2}$ per cent.) at maxima to 38·02 for the eighteen years at minima. The September values are 45·19 (+48 per cent.) and 30·53 respectively; October, 49·61 (+39 per cent.) and 35·62 inches.

The relation is so regular from cycle to cycle that mere coincidence seems improbable.

The monthly and whole-year values were next sorted out for the six cycles, according as they came in the first, second, third, &c., year of the cycle. Year I. was taken for minimum solar activity (as shown by Wolf and Wolfer's sun-spot values), and VI. for maximum, each cycle being reduced to a mean length of eleven years. The whole-year results showed a strong minimum in II. and maximum in VI., with a secondary maximum at III. practically equal.

The three-bloxamed curve gives the minimum at I. and maximum at V. The three autumn months again give the most striking monthly values, August being the reverse of the other two. This, indeed, is very marked if the curves from year to year are three-bloxamed, and the relation to solar activity is strikingly brought out by the three curves combined on the formula $\frac{S+O}{2} - A$. Similar curves for $\frac{S+O}{2} - A$ for Aysgarth (Yorks) and Street (Somerset) also resemble that for York, the short period at Aysgarth following the solar curve very closely.

Combining the six cycles, we get for $\frac{S+O}{2} - A$ at York, 1831-1904, a *continuous curve*. The minimum is -1·8 inches in I.; the maximum +0·6 inches in VI. to VIII. A lag like this and tendency to hump at about IX. is not infrequent.

London (from 1797), Exeter (1815, on), and Rothesay (1800) give similar curves for $\frac{S+O}{2} - A$. The early Uppingham series (1736-98) give similar, though less accentuated, results.

York rainy days (three-bloxamed) again correspond, but the mean temperature is less certain ($-6\ 9^{\circ}$ at II. to -9° at V., unbloxamed).

Similar comparisons were made for Brückner's thirty-five-year cycle. Starting from 1831 and 1866, the solar activity curve, after eliminating the eleven-year cycle, showed a strong maximum in VI. (active years from II. to XIX.) and minimum at XXV. York rainfall values again indicate correspondences, with, as a rule, excess of rain from II. to XIX. Again the curve for $\frac{S+O}{2} - A$ is suggestively similar to that of solar activity.

6. *Some Barometric and Rainfall Changes of an Oscillatory Nature.*

By WILLIAM J. S. LOCKYER, M.A., Ph.D., F.R.A.S.

This paper referred, in the first place, to the barometric changes taking place in the earth's atmosphere of durations the length of which amounted to three or nearly four years.

The author pointed out the see-saw nature of these changes at opposite sides

of the earth, the Indian area representing the centre of one region, while that of South America was typical of the opposite or reverse change. It was then shown that the rainfall underwent changes which were closely related to this pressure-variation of short duration.

The author then referred to an investigation he had recently communicated to the Royal Society (vol. lxxviii., p. 43), in which pressure-changes of longer duration were examined.

It was thought possible that similar barometric see-saws might occur with regard to the changes of long duration as were found for those of short duration.

The result of the inquiry indicated that, while there was a variation of about eleven years' duration occurring in India, a nineteen-year variation was conspicuous in the Australian and South American areas.

In the case of the last two mentioned areas the phases were neither coincident nor reverse, but there seemed to be a lag of about six years.

It was finally suggested that, as the Australian variation was closely allied to the Indian change, and as the Indian pressure-change is closely similar to the reverse of the sun-spot variation, the Australian nineteen-year cycle was possibly of solar origin, and not necessarily due to lunar influence.

7. *Report on the Magnetic Observations at Falmouth Observatory.*

See Reports, p. 90.

8. *Preliminary Report on the Magnetic Survey of South Africa.*

See Reports, p. 131.

9. *Report on Meteorological Observations on Ben Nevis.*

See Reports, p. 91.

DEPARTMENT OF GENERAL PHYSICS.

The following Papers were read:—

1. *A Glass of Low Resistivity.* By CHARLES E. S. PHILLIPS.

A glass which conducts electricity comparatively well may be obtained by fusing together sodium silicate and borax in the following proportions, viz.,

Sodium silicate	:	:	:	:	:	32 parts.
Calcined borax	.	:	:	:	:	8 parts.

If to this mixture 1.25 parts of Powell's flint glass be added, greater stability results, and the surface is improved without any serious loss of conductivity.

A glass suitable for the cases or windows of electrostatic instruments may thus be produced, capable of being cast into plates, but on account of its low fusion-point not otherwise very workable. It may, of course, be readily drawn into rods or fibres, and takes a fine polish.

The density of the glass is 2.490, and it is somewhat harder than the ordinary soda glass of commerce.

With regard to other physical properties, it shows no fluorescence under cathode radiation, is very transparent to x -rays and opaque to ultra-violet light. Its electrical conductivity is about 500 times that of the most conducting glass so far made. The specific resistance of an average sample is of the order 10^9 ohms at 20° C., which, although high in itself, is exceedingly low for glass. When powdered and fused on to clean copper it adheres well without cracking. The change of resistivity with heat (which is very marked) is being examined.

The writer's best thanks are due to Messrs. James Powell & Son, of London, for the very generous help which they have given in connection with the production of this glass and for the interest they have kindly taken in the experiments.

2. *Radiation from Gas-Mantles.* By J. SWINBURNE.

As the object of this paper is to stimulate a discussion in order to elucidate the subject, I will state one point of view and oppose some others, inviting criticism, even if quite destructive; and see what happens.

The ordinary explanation of the great luminous efficiency of the gas-mantle is that rare earths have a property of selective radiation, in virtue of which they send out a larger proportion of their radiant energy in the form of light than ordinary hot bodies.

Other explanations are that there is catalytic action going on; that cerium has two oxides and oscillates between the two states, and this produces the effect.

Another explanation, first given, I believe, by Ram ('Incandescent Lamp,' p. 196), is that the Bunsen flame is really very hot, and that the mantle is of such low emissivity that it gets rid of so little power that there is little difference of temperature between it and the flame, and it is therefore hot enough to give the light by pure temperature radiation, without any anomaly.

One reason why the simple temperature explanation has been questioned is that the temperature of the Bunsen is generally taken to be much lower than it is. It is generally measured by means of platinum wires or thermo couples. These can never rise to the real temperature of the flame, as they are radiating and must therefore be taking in heat by conduction, in which case they must be cooler than their surroundings.

The simple temperature explanation fits the phenomena. If pure thoria has low emissivity it will rise to a temperature near that of the shell of flame bathing it. Having low emissivity it will then give out little light, but the light will have a large proportion of visible and refrangible rays. If a very little of a body with a high emissivity be added, radiation will increase, but the temperature of the mantle will fall, as there must be a steeper heat-gradient to supply it. The total radiation is then increased, and though the proportion which is luminous will be diminished, the total light will be increased. Further addition of the emissive substance increases the total radiation and reduces the temperature until the light given is less even than with pure thoria.

By selective radiation may be meant that a body at the temperature of a black body emits some rays, and omits others, or that it has the power of emitting more refrangible rays than a black body at the same temperature. If two black bodies are in a reflecting envelope, at the same temperature, each radiates to the other, and absorbs power from the other. The heat in each is in a state of degradation corresponding to the temperature, and in a state of equilibrium it must be radiated and absorbed by each without further degradation. Heat radiated from a black body into a closed space in equilibrium is thus not degraded. If a body only emits the portion of the rays of high frequency, though it may radiate less power or energy per second, that energy must surely be of a higher grade than that of the black body at the same temperature, because it can be degraded into radiation of lower frequency. If that is so, this sort of selective radiation violates the second law. Emitting more refrangible rays than the black body is worse still. It does not follow from this that a body cannot emit rays of high frequency balanced by another batch at low frequency, so that their degradation corresponds with the temperature. This form of selective emissivity has not yet been invented by the advocates of this theory.

The catalytic action theory is vague. Generally catalytic action merely accelerates a change from unstable to stable equilibrium. It is difficult to see how catalytic action can affect radiation. A suggestion may be made. The

gases in the hot shell combine at a certain rate, and the flame radiates heat, and comes up to a certain temperature. If the mantle causes quick combination intimately among its own particles, it may be possible that the temperature there may be higher than in the flame itself, so that the mantle may really be hotter than the flame. I have not seen this idea put forward. It is not needed to explain the phenomena, and it would be curious that all the bodies capable of increasing the light of pure thoria should be coloured oxides.

It is sometimes urged that the particles of rare earths have a special way of vibrating in resonance with the particles of hot gas, and thus radiate light preferably. This, again, would mean elevating heat energy to a grade higher than that corresponding to the temperature, without rejection of heat at a lower temperature; a violation of the second law.

The same reasoning holds against the theory that ceria oscillates between two states of oxidation. If it did it could not supply energy by such means, and therefore could not deliver energy supplied as heat at a grade higher than that corresponding to the temperature of the body.

3. *The Rate of Decay of the Phosphorescence of Balmain's Paint.*

By the Rev. B. J. WHITESIDE, S.J.

The knowledge of the rate of decay of phosphorescence is one which is of great interest in connection with the question of the form under which the energy of phosphorescence is stored.

With the view of helping to elucidate this question, experiments were made with Balmain's paint to determine the rate at which luminosity falls off with time.

The method adopted was a modified inverse square photometer. A square of the phosphorescent material was compared with a square of similarly tinted glass illuminated from behind by means of an incandescent electric lamp. A plate with a small hole was placed in front of the lamp to limit the source. This arrangement was moved by means of an endless coil and wheel, so as to enable the observer to vary the intensity of the illumination of the matching square according as the intensity of the phosphorescence diminished.

Metallic contact-pieces were placed round the wheel, so that as it was rotated a series of electric currents could be obtained. These were led to a chronograph, and thus the position of the source of light at any moment recorded.

The procedure in an experiment was first to illuminate the phosphorescent material for a given time by means of an arc lamp. Then as soon as possible the photometer light was brought to such a distance that the matching square looked as bright as the phosphorescent material. The observer then endeavoured by turning the wheel to keep the matching square of an equal brightness with the phosphorescent material. A record of this was obtained from the chronograph.

The results obtained were found to agree with a simple hyperbolic law, $I = 1/(a + bt)$. This differs altogether from the law propounded by Becquerel from theoretical grounds—namely, $I = 1/(a + bt)^2$.

It is of interest to note that the rate of recovery of over-strained solids has been shown to obey a simple hyperbolic law. This fact is suggestive in connection with the well-known fact that only solid materials are capable of phosphorescing, and would lead to the supposition that phosphorescent light is only a secondary effect arising in connection with the recovery of the solid from an over-strained condition.

4. *Chemical and Electrical Changes induced by Ultra-violet Light.*

By Sir WILLIAM RAMSAY, K.C.B., and J. F. SPENCER, M.Sc., Ph.D.

1. Light from an iron arc, falling on earth-connected plates of elements, placed at an angle of 45° to the cap of an electroscope, discharges the electroscope. Even when an aluminium box earthed, the top closed with a gold or silver leaf so as

to surround the plate of the electroscope completely, was interposed, discharge still occurred; but it became very slight when a thin aluminium leaf was substituted for the gold or silver. Discharge occurred when the electroscope was charged positively, but not negatively. The charge was approximately 800 volts.

2. As the iron arc proved unsteady, a Cooper Hewitt uvioi-glass mercury lamp was substituted. The illumination was insufficient to cause discharge through gold or silver leaf, but took place when the plate of the electroscope was exposed to the reflections. The rate of discharge caused by plates of forty elements, metals and non-metals, was in the order of their position in the electric series, gold, iron, and manganese being notable exceptions. No discharge took place if the electroscope were negatively charged.

3. The rate of discharge was greatly increased, and this order was practically the same, when the plates formed part of the electroscope; in this case, however, it was necessary to charge the electroscope negatively, and again to 800 volts.

4. The sulphides of a number of the metals in the form of plates also caused discharge, but at a much slower rate; some iodides were also measured and found to cause discharge. The order, however, is quite distinct from that of the elements.

5. The plates gave a more rapid discharge with a fresh surface: they 'tired' however, and the rate of falling off presented some peculiarities. For dyad metals the curve presents two obvious 'breaks,' and two places of constant rate of 'tiring'; for tetrad metals, four such stages were observed.

6. A unifluid cell, containing two identical plates of copper, cadmium, or gold, gives a small change of potential when one plate is illuminated by ultra-violet or sunlight in a tube of uvioi-glass, the other plate being kept in the dark. That chemical action had occurred was obvious on examining the exposed plate.

All these phenomena are brought into line on the hypothesis that elements and compounds when illuminated discharge corpuscles.

5. *Researches on nearly Pure Ozone Gas.* By ERICH LADENBURG, *Ph.D.*

By allowing liquid ozone to vaporise into a vacuum tube nearly pure ozone gas is obtained, which has a dark-blue colour in a thickness of 30 cms. The absorption spectrum of this gas from 0.22μ to 12.2μ was now examined, and some new bands were found. There are five new bands which do not belong to ozone, but always appear when the liquid ozone is allowed to vaporise. The gas to which they belong can be separated from ozone. The oxygen which was used for making the ozone was developed by electrolysis of boiled potassium hydrate, and was therefore as pure as possible. It seems, therefore, very probable that this gas is a new modification of oxygen, and this being the case it must be of higher molecular weight than ozone, because the pressure of the gas increases with the disappearance of the five bands. The determination of the specific gravity of this gas has proved the truth of this opinion.

6. *Photographs of Thin Liquid Films.* By HERBERT STANSFIELD.

The photographs were taken with a camera specially constructed for photographing the structure of plane vertical films by reflected light.¹ They were arranged to show the series of abrupt changes in thickness that take place during the thinning of films formed from solutions of sodium and potassium oleate. Both these solutions show two black stages and three greys intermediate between the coloured part of the film and the black. The photographs also showed the way in which solid material separates out in the films.

¹ See *Proc. Roy. Soc., A*, vol. lxxvii., 1906, p. 314.

7. *Photographic Records of a String's Vibrations and Responsive Motions in the Air.* By Professor E. H. BARTON, D.Sc., F.R.S.E., and J. PENZER.

When a musical string is struck, bowed, or plucked, the consequent motion of the string itself is known from the analysis and experimental researches of Helmholtz and others. But the quality of the sound perceived by an auditor is not dependent simply on that due to the relative intensities of the partials present in the string's motion. For the greater part of the sound received does not come directly from the string, but from sympathetically vibrating parts of the instrument on which the string is mounted. And as the bridge, sound-box, and contained air in turn respond to the motion of the string, probably each introduces its own partialities and exaggerations into the aggregate of vibrations communicated to it. It is therefore desirable to ascertain how the motion of each member of this series of moving parts is related to that of the string. The first instalment along these lines¹ dealt with the string of a monochord and the belly or top of its sound-box. The present paper is a second instalment of the work, and deals with the string of the same instrument and the motion of the air in and out of the central hole of the sound-box.

To record the motion of the air, this hole was covered with a thin animal membrane, the motion of whose centre pulled and pushed an aluminium stalk, and so rocked a small plane mirror. The axis of the mirror was a sewing needle held in a horizontal position by brass brackets on the vertical face of the sound-box. The mirror reflected the light from an arc lamp to a photographic plate about 6 feet distant. Thus the rocking motion of the mirror caused the spot of light to rise and fall. A simultaneous uniform horizontal motion of the plate along rails drew out the trace into the desired displacement-time curve forming the record of the vibrations in question. In the positive print this is a bright wavy line on a dark ground. The string's motion was recorded as a black line on a white ground by its crossing the real image of a slit focussed first upon the string and then upon the sensitive plate. Thus the two photographic traces are simultaneously obtained, and show the relation of amplitude and phase which held at the time of exposure. On the negatives the magnification of the diaphragm's motion is about 4,200 times, and that of the string's about three times. Thus on the reduced prints, though each is diminished, the relative magnification of the diaphragm to the string remains the same, namely, about 1,400.

8. *Haidinger's Tufts.* By Professor W. F. BARRETT, F.R.S.

In 1844 the distinguished geologist and physicist Dr. W. Haidinger, of Vienna, discovered the curious fact that when a bright sky or any brightly illuminated surface was looked at through a Nicol's prism, a pair of small yellow cones, joined apex to apex, was seen in the direct line of vision. At right angles, and filling the larger space on each side of these cones, a faint blue or violet colour was seen. Haidinger called this appearance by the German word *büschel*, which means a tuft—in French *houppes*. Strangely enough, they have been incorrectly termed 'brushes' in English, and are usually known as 'Haidinger's brushes.'² The yellow tufts resemble an hour-glass; and I would suggest the name of *fasciula lutea* for them, inasmuch as this would have the advantage of a verbal connection with the *macula lutea*, or yellow spot, of the eye, with which they are closely associated. For, as is well known, the origin of the yellow tufts does not arise from any cause external to the eye; they are not an *exoptical*, but an *entoptical* phenomenon. How

¹ *Phil. Mag.*, July 1905.

² Sir D. Brewster, in his *Optics*, p. 246, speaks of them as 'brushes,' 'tufts,' 'sectors,' and in several places as 'bushels'!

they originate has long been the subject of controversy, and will be discussed presently.

The longer axis of the yellow tufts, or hour-glass, coincides with the plane of polarisation of the incident light, and therefore rotates with the rotation of the Nicol. If the Nicol prism be kept unmoved before the eye the appearance vanishes in a few seconds; when the Nicol is suddenly turned to a different plane the tufts reappear, fading again in a few seconds if the Nicol be unmoved. This fugitive appearance is characteristic of several other entoptic phenomena, and explains why so many observers have failed to see Haidinger's tufts. Sir D. Brewster states that he tried in vain for over twelve months before he saw them; von Helmholtz remarks that in spite of the greatest efforts it was twelve years before he perceived them. There is not, however, the least difficulty in seeing them if the following details are attended to. Choose a bright sky or a sheet of paper brightly illuminated with white light; hold the Nicol before one eye, and close the other; turn the Nicol backwards and forwards every two or three seconds, and the tufts will be seen projected on the illuminated surface at the extremity of the optic axis. If the observer still fails to see them, hold a piece of cobalt-blue glass in front of the Nicol, and a dark-reddish hour-glass-shaped patch will be distinctly seen. The cobalt blue transmits the extreme red rays. By keeping the Nicol in slow rotation the tufts can be continuously seen.

When the tufts are seen projected on a white surface, if the plane of polarisation be horizontal and the Nicol suddenly removed from the eye, the tufts will still be seen faintly, but in a vertical plane. This is no doubt due to the partial polarisation of the light reflected from the white surface, for the effect is more marked if a polished black surface be employed. The light of the sky is polarised 90° from the sun; hence those familiar with the appearance of the tufts can see them, without the aid of a Nicol, by looking at a bright sky in a position at right angles to the sun, or at any non-metallic polished surface. The unaided eye can thus detect not only polarised light, but also determine its plane of polarisation.

At the British Association meeting in 1850 Sir G. Stokes showed that the tufts could not be seen in light of lower refrangibility than the green. If a spectrum be projected on a white surface and the colours successively looked at from the red to the violet through a Nicol's prism, the tufts will first appear in the green, about the F line, and remain visible, if the Nicol be kept moving, until the limit of the visible spectrum is reached.

The origin of Haidinger's tufts has been a subject of considerable discussion. There must obviously be some medium in the eye which is able to act as an analyser to polarised light. Silbermann in 1846 showed that both the cornea and the crystalline lens were bi-refracting, and he concluded that the lens was the source of the tufts. But Zokalski, an eminent Paris oculist, subsequently found that four aphakic patients (those whose lens had been removed) were able to see Haidinger's tufts. Jamin, in 1848, urged the corneal origin of the tufts, and succeeded in fairly well reproducing their shape by making an artificial cornea of a pile of watch-glasses pressed together, and examining the system by polarised light. But Brewster, in a little known but valuable paper in the 'Comptes Rendus' for 1859, conclusively proved that the cornea could not be the seat of the appearance. For there was no alteration in the size or shape of the tufts when an opaque screen with a very minute circular aperture was held before the eye, nor when a narrow slit was used and slowly rotated before the eye. The tufts were seen more faintly, but that was all.

Brewster maintained that the origin of the tufts must be sought for in the region of the eye at the extremity of the optic axis, and concluded that their cause was due to some bi-refracting property possessed by the *fovea centralis* of the retina. This was also the view held later on by Helmholtz, who pointed out that many organic fibres and membranes are bi-refracting, and act in general like uniaxial crystals. The production of the tufts could therefore be explained by assuming that the fibrous layer of the macula (the yellow spot) was bi-refracting, absorbing the extraordinary ray more strongly than the ordinary. The peculiar

shape of the tufts Helmholtz suggests is due to the shape of the *fovea*, which (in agreement with Brewster, though he does not refer to him) he considers is the seat and cause of the appearance.

Prior to either Brewster or Helmholtz, Clerk Maxwell, in a communication to the British Association in 1856, had shown how, by an absorbent medium, any observer could see the yellow spot of his own eye,¹ and he remarks: 'By using a Nicol the brushes of Haidinger are well seen in connection with the yellow spot, and the fact that the brushes being the spot analysed by polarised light becomes evident.' This is the earliest suggestion of the true origin of the tufts. The best coloured screen for seeing the yellow spot is that suggested by Mr. Whitmell—viz., a weak solution of the double oxalate of chromium and potassium, which is quite opaque to the yellow and orange rays. Looking at the sky or any illuminated surface through such a screen, everyone can distinctly see the yellow spot in his eye, as a nearly circular dark red patch. If now a Nicol be held before the eye, Haidinger's tufts are seen exactly coincident with the yellow spot, the longer axis of the tufts corresponding to the diameter of the yellow spot. The *macula lutea* and the tufts (or *fascicula lutea*) are therefore identical in position in the retina, though their shape differs. The faint blue light seen by some but not all persons at right angles to the yellow tufts can hardly be, as Jamin has suggested, a *contrast effect*—the blue tint being complementary to the yellow—for the blue tint is seen when a polished black surface is looked at, and some persons see the blue sectors better than the yellow.

I am disposed to think that the production of the tufts is due to the combined action of the bi-refracting film of the cornea, together with the polarising structure of the yellow spot. That neither the cornea nor the crystalline lens are alone concerned in their production has already been shown, and can be conclusively demonstrated by using the instrument which I have termed the *entoptiscope*, a description of which is published in recent 'Proceedings' of the Royal Dublin Society.² A simple device can, however, be employed. An opaque screen with two pin-hole apertures, each 1 mm. in diameter and 2 mm. apart, held between the eye and the Nicol's prism, would give a double image of Haidinger's tufts if they were due alone to the refracting media of the eye; but only a single image of the tufts is seen; hence their detection is due to the retina.

No observer has hitherto measured the actual *retinal area* occupied by Haidinger's tufts. This can readily be found if the distance of the nodal point, or optical centre of the eye, from the retina is known. In a normal eye the nodal point is 16 mm. from the retina. Now the angle subtended by the tufts is between 3° and 4°. Calling this angle α , and the distance of the nodal point κ , the retinal image will be $= 2\kappa \sin \frac{\alpha}{2}$, which gives a length of about 1 mm. for the

longer axis of the tufts. A more accurate method is to measure the length of the projected image of the tufts on a white sheet of paper at a known distance from the eye. The distance of the nodal point from the retina being known (and this distance varies from 13 mm. in hypermetropic eyes to 18 mm. in myopic eyes), the retinal area of the tufts can be accurately found. In my own case, and in that of two or three of my assistants who have tried, I find the retinal area major axis of the tufts to be from 0.8 to 1.0 mm.

Now the longer axis of the *fovea centralis* is only 0.2 mm. The tufts cannot, therefore, be restricted to the *fovea*. But the diameter of the yellow spot, the *macula lutea*, exactly corresponds to that of the tufts—viz., 0.8 to 1.0 mm. Hence Haidinger's tufts are not due, as Brewster and Helmholtz thought, to the *fovea*, but to the whole yellow spot, and doubtless are caused by some polarising property possessed by the structure of the bacillary layer of the retina in that spot. Throughout the yellow spot the rods of the bacillary layer are absent, the

¹ The use of an absorbent medium, a weak solution of chromium chloride, for observing the yellow spot in one's own eye was, as Clerk Maxwell points out, first suggested by Stokes.

² *Proc. Roy. Dub. Soc.*, May 1906.

cones only being present ; and it would therefore seem as if a close connection existed between this peculiar retinal structure and the detection of polarised light and the plane of polarisation by the unaided eye.

9. *Report of the Committee on Electrical Standards.*

See Reports, p. 104.

10. *Joint Discussion with Section E on the Proposed Remcasurement of the British Geodetic Arcs.*—See p. 626.

SECTION B.—CHEMISTRY.

PRESIDENT OF THE SECTION—Professor WYNDHAM DUNSTAN,
M.A., LL.D., F.R.S.

THURSDAY, AUGUST 2.

The President delivered the following address:—

Some Imperial Aspects of Applied Chemistry.

THE President of the Chemical Section of the British Association must always have a large choice of subjects for his Address. He may attempt to review the chemical progress of the year, or to give an account of researches in that division of the science in which he is most interested. He may deal with the ever-recurring problems of education; or, again, he may draw attention to the importance of our science in one or other of its many relations to National and Imperial affairs. I have decided to adopt the last course, and to invite your attention at York, where several tropical products furnish the basis of important industries, to the intimate association of our science with the problems that await solution in connection with the utilisation of the raw materials and economic products of our Colonies, and especially those of our tropical Possessions. There is a pressing need that the Imperial Government should recognise much more fully than it has hitherto done, and at least as fully as foreign Governments are already doing, the claims of scientific investigation to be regarded as the pioneer instrument of this work, and as the essential first step in the material and commercial development of our Possessions.

Although my remarks will be chiefly directed to the importance of chemistry in this connection, my plea will be more general. It is that the scientific method of experimental research should be systematically applied in each division of the sciences concerned. In the case of raw materials, however, whether vegetable or mineral, their commercial value must depend chiefly, if not entirely, upon their composition, and sooner or later the method of chemistry must therefore be applied.

In determining the value of the mineral resources of a country other specialists are also concerned, and the assistance of the geologist, the mineralogist, and eventually of the metallurgist may be required. Similarly with vegetable and agricultural products the services of the economic botanist and of the entomologist will be needed. It will therefore be necessary for me in dealing with the subject as a whole to touch upon several aspects in which other sciences are concerned, and with which the science of chemistry must co-operate in attaining a practical end—namely, the material development of the countries concerned. I need make no apology for many allusions to scientific agriculture, for this subject is this year attached to this Section, and indeed the science of chemistry is of fundamental importance to agricultural practice both at home and in the tropics.

In the first place I must ask you to allow me to say a few words as to the very

wide interests that are involved in the proper solution of the problem of colonial development.

It is all-important that the wage-earning community of this country should have an adequate supply of tea, coffee, cocoa, rice, tobacco, and other commodities, and that our manufacturers should be able to count upon a regular supply of cotton, jute, rubber, and other raw materials as far as possible under their own control. All these products are derived almost exclusively from the tropics, and experience shows that it is a great disadvantage to the manufacturer not to be able to exercise control in the direction of securing the regular production of these materials, and especially not to be able to avoid the great and sudden fluctuations in their price, which are often the result of financial speculation on the part of a foreign capitalist who has secured the control of the output of a foreign country.

The almost entire dependence of the great textile industries of Lancashire upon the cotton crop of the Southern States of America has placed this industry at the mercy of American speculators, whose tactics may lead, as in 1903, to such a rise in the price of the raw material as to render it imperative for the manufacturer to close his mills, and by throwing large numbers out of employment to bring poverty and misery to many thousands of people.

The great principle which must now necessarily guide our system of administration and expenditure in our tropical Colonies and Protectorates has as its purpose the utilisation of natural resources and the creation and development of native industries with the aid of European supervision and advice. Adequate supplies of produce, natural and agricultural, will thus be ensured to British manufacturers and consumers from territories within the administration of the British Crown. This principle of employing our 'undeveloped estates' for the advantage of our manufacturers and consumers, and at the same time for the benefit of the natives who inhabit these countries, was put into action by Mr. Chamberlain during his long tenure of office as Secretary of State for the Colonies, and this recognition of a vitally important principle must always be associated with his name.

Excepting India and the self-governing Colonies, the Crown Colonies and Protectorates, for which alone the Imperial Government is directly responsible, include an area of about two and a half million square miles and a population of about forty millions. The value of these possessions to us at the present time may be judged from the value of their import and export trade with the United Kingdom. The value of the exports of these countries in 1904 was estimated at about four and a half million pounds sterling, and the imports from the United Kingdom at about twelve and a half million pounds sterling. In gauging the importance to this country of the development of these Possessions, the export trade of which is only in its infancy, it should be remembered that the profits arising from the export as well as from the import trade are chiefly domiciled in this country; since practically the whole of this trade is in the hands of British merchants, and the entire profits, including those of shipping, &c., are therefore subject to our national system of taxation, and represent a very substantial annual contribution to the British Exchequer.

It is therefore only reasonable that a certain sum should be expended from British funds to aid the applications of science to the commercial development of these Possessions. Such an expenditure in the light of the facts to which I have drawn attention may be regarded as an investment with the certainty of a profitable return.

I have thought it necessary to give this brief account of the position of our still undeveloped Crown Colonies and Protectorates and the national importance to us of their systematic development before proceeding to the principal subject of this Address, which is to emphasise the aid which science in several of its branches can render to this work of development, and especially the science of chemistry, the capacities of which in this connection have so far not been sufficiently recognised.

The importance of utilising our own tropical Possessions as sources of the raw

material required by the manufacturer is now generally recognised, and very considerable progress has been made in recent years. The tea produced in India and Ceylon has largely superseded the China tea formerly used in this country. Similarly, coffee is extensively grown in India, in the West Indies, and in several of our African Possessions. The jute cultivation in India has been very successful, and the demand for this fibre is so great that the question of its cultivation in our West African Colonies is now under consideration. Indiarubber, hitherto chiefly obtained from South America, is of increasing importance as a commercial article, and the South American tree has been introduced with success in Ceylon, the Straits Settlements, and the Federated Malay States, which are rapidly becoming important rubber-producing countries whose produce is competing successfully with that of South America. The cultivation of cotton, hitherto principally carried on in the United States, is being vigorously proceeded with in India, the West Indies, and in West Africa, as well as in Egypt and the Sudan, and we may look forward in the future to these countries supplying the British manufacturer with a large proportion, if not the whole, of the cotton he requires.

There are, however, vast resources, both mineral and vegetable, in our Colonies and Protectorates which are awaiting development for an exact knowledge of their composition and properties, which can only be ascertained by scientific means and chiefly through chemical investigation, whilst the British manufacturer is in need of increased and better supplies of the raw materials on which his industrial activity depends. This demand for increased supplies now affects nearly every industry in this country. Rubber and fibres are well-known examples; oils and fats for the manufacture of soap and perfumes; and tanning materials, as well as numerous minerals, are other instances in which our manufacturers are at present anxious to discover new sources of supply. These sources can only be discovered and their value ascertained by properly directed scientific investigations.

We have heard much recently respecting the assistance which science can bring to the maintenance and development of the industrial efficiency of this country, and the Imperial Government is being urged to give its help especially by providing increased facilities for the education of scientific men, competent to aid the manufacturers of this country in improving their methods and processes. In this work the science of chemistry is one of the most important. There is scarcely an industry to which it is not able to render immense service. Within recent years this fact has slowly gained recognition, and the principle of State assistance to industry is virtually admitted, both in respect of education and of research. The most conspicuous examples of a recognition of the principle are the grants made from the National Treasury to the new Technological College at South Kensington and to the National Physical Laboratory.

Not less important than the service which science can render to existing industries and their extension is that which it can contribute to the Imperial problem of ascertaining and rendering available for the manufacturer the vast undeveloped resources of our own Possessions. Our own experience and the example of other countries have shown that such work cannot be systematically carried on by private enterprise. Upon its successful accomplishment depends, not only the unrestricted supply of the necessary raw materials for which the manufacturer looks in increasing quantity, but also the prosperity of the country which produces these materials. This success can only be brought about by a combined effort on the part of the manufacturer and of the Government. The manufacturer can provide information as to the materials he needs. The preliminary work of discovering suitable material by scientific means, as several foreign Governments have already recognised, must be endowed, directed, and carried on with Imperial funds. It cannot be expected that private enterprise will take steps to explore the resources of little-known countries on the chance of a particular material being discovered, nor can the work, as a rule, be successfully done by this means. Experience shows that the most effective manner of promoting the commercial development of a new country is for the Government to carry out systematically with its own officers the preliminary work of exploration and examination of the

natural resources, with the aid of such technical advice as may be necessary from manufacturers and users, and then, having established the fact that particular products of value can be found or cultivated in a given country, to leave commercial enterprise to do the rest. By action on these lines immense progress is being made in French, German, and Dutch Possessions, whilst the United States Government has taken similar action with the Philippines. In our own case, where this work exists it is in most cases in a more or less embryonic condition, and lacks the organisation which is necessary for success.

In many of our Crown Colonies and Protectorates there already exist, or are in the process of organisation, agricultural and other scientific departments, many of which include officers who are engaged in the work of exploring and developing the vegetable resources of these countries especially by experimental planting. Chemists are attached to some, but not to all of these departments. In the West Indies the valuable work accomplished by Professor Harrison, Mr. Francis Watts, Professor Albuquerque, Professor Carmody, and Mr. Cousins is well known, and illustrates the great services which the science of chemistry may render, not only to tropical agriculture, but to every branch of economic development. It is clearly desirable that at least one scientific department should be attached to the Government of each of the principal Crown Colonies and Protectorates. As a rule, it is convenient that this should be an agricultural department with the services of a scientific chemist at its disposal. In a tropical climate, and with limited appliances at his command, it must be admitted that a chemist is severely handicapped, and, as a rule, he cannot be expected at first to be able to do much beyond the comparatively simple and preliminary work, chiefly analytical, which, however, in a little known country is of the greatest importance to an agricultural department. In addition, he would have to deal with the composition of natural products of all kinds, both vegetable and mineral, as well as with the improvement of native industries. If the chemist is able to refer complicated or special investigations to a central department at home, and is provided with assistance in the routine work, he would be in a position to undertake the scientific investigation of a selection from the numerous problems with which a chemist will be confronted.

A chemist working in the spirit of an investigator will be able to render special services to the cause of tropical agriculture, and it is therefore of importance that in future the men appointed to these posts should be chosen as far as possible on account of the promise they have shown as investigators. The determination of the constituents of little known indigenous plants as the first step towards ascertaining their economic value is another department of work which cannot be carried out without a chemist, and the same applies to the examination of poisonous plants, and also of minerals, in addition to the determination of the composition of foods and feeding stuffs.

Tropical agriculture is a subject which is now of the first importance, especially in those countries in which our policy is to depend on a native population for the actual cultivation of the soil. We have two functions to perform in our position as supervisors: the one is to ascertain the nature and capabilities of the soil by actual experiment, for which well-organised experimental stations are a necessary part of every agricultural department; the other duty is to convey to the natives, chiefly by means of demonstration, the results of this experimental work, so that they may be persuaded to make it a part of their agricultural practice.

Work on these lines is being done under Government auspices in the French and German Colonies, and I may allude to the French successes in Algeria, in Senegal, and in the Sudan, and to the advances made by Germany in East Africa. These achievements are mainly due to a policy of continuous scientific work on agricultural lines. We shall have the privilege of hearing from Dr. Greshoff, the eminent director of the Colonial Museum at Haarlem, an account of the chemical investigations which are being carried out in connection with Java and the Dutch East Indies.

In many of our own Colonies and Protectorates active agricultural depart-

ments, equipped with the means of experimental working, are only now in process of organisation. One of the most recently organised of these is that of the Transvaal, which, at Lord Milner's initiation, has been completely equipped on the lines of that model for all such effort, the agricultural department of the United States. This department has as its chief chemist Mr. Herbert Ingles, of the Yorkshire College, now the University of Leeds.

If we are to compete successfully with foreign countries it is necessary that the position of science in relation to tropical agriculture should be definitely recognised. The days when a botanical garden served the purpose of an entire scientific establishment in a Colony have passed away, and we now require, in order that a proper return should be obtained, and the natives assisted in their agricultural practice, a scientific department with a proper complement of specially trained officers, including a consulting chemist, other specialists being added to the staff as the requirements arise. These officers should be remunerated on a scale likely to attract some of the best educated men from this country, which is at present far from being the case.

It would be out of place to discuss here the detailed organisations of these scientific departments. I merely desire to urge the necessity of their functions being extended, and of their receiving adequate financial support.

It is important that the scientific work which is being accomplished by these various departments should be brought to a focus, and that the results obtained in one Colony should be available for the information of the departments in other Colonies. The work of all such establishments requires to be unified by co-operation with a Central Department which can extend the investigations conducted in the Colonies, carry out investigations and inquiries which cannot be undertaken on the spot, maintain the necessary touch with the manufacturers, and co-ordinate the work undertaken and the results obtained in each of the separate Colonial establishments and systematically collate it, so that each may be aware of the results that are being obtained in other countries. In our African Possessions at present the same investigations and inquiries have to be conducted independently, and often without the knowledge that the problem in question has been already solved.

Another increasingly urgent duty of the Central Department is to inform the Colonial establishments of the results of the work which is being conducted in foreign countries, and of the progress which is being made in the utilisation of raw materials all over the world, and to bring to their notice the constantly changing requirements of the manufacturers and users of raw materials.

So far as botany is concerned, this co-ordination has been to a large extent effected through the agency of the Royal Gardens, Kew, which is in touch, through the Colonial Office, with all the botanical gardens in the Crown Colonies and Protectorates. In chemistry, as well as in certain other subjects, these duties have been performed in recent years by the Scientific and Technical Department of the Imperial Institute, which is now working in co-operation, not only with the Governments of the Crown Colonies and Protectorates, but also with those of several of the self-governing Colonies, and also with the Scientific Departments which have been brought into existence in India, where at last the importance of scientific agriculture is receiving due recognition from the Government.

So little has hitherto been done in this direction that the number of problems requiring attention is exceedingly large; and even with a specially trained staff of workers and extensive laboratories, such as now exist at the Imperial Institute, it becomes necessary to select as the principal subjects for investigation those which are regarded by the Governments of the countries concerned as of the most practical importance, and in which the British manufacturer is at the moment most concerned. There must therefore remain a large number of materials of unknown composition and of problems of purely scientific interest which offer an attractive field for the chemical investigator. Already steps have been taken to provide for the investigation of these subjects by scientific men who are willing to undertake them in communication with the Institute. For example, Mr. A. G. Perkin, F.R.S., has been furnished with material which has led to the identification and

determination of the constitution of the colouring matters of a number of plants which are employed as dyes in India and the Colonies. Professor A. H. Church, F.R.S., has determined the composition of many new or little known food grains. Dr. Crossley, Dr. Le Sueur, and Dr. Lewkowitsch have examined the constituents of a large number of fats and oils furnished by seeds of Indian and African origin. Dr. W. J. Russell, F.R.S., has been furnished with selected materials for examination in connection with his interesting investigations of those substances which affect the photographic plate in the dark, whilst the Hon. R. J. Strutt, F.R.S., has investigated the radioactivity of a number of new or little known minerals containing rare earths. Last year over 500 different materials and problems were submitted from the Colonies and India for investigation to the Scientific Department of the Imperial Institute, and each year there must remain an increasing number of interesting subjects which cannot be included in the Department's annual programme of work. Many of these would furnish excellent subjects for chemical research by advanced students in connection with the universities and technical colleges throughout the country. It is nearly always possible to arrange to furnish the necessary material for any competent worker to deal with. Next year a list of such subjects awaiting investigation will be available at the Imperial Institute for those in search of subjects for chemical research.

Whilst the investigation of some of these subjects may at once produce results of scientific value, many of them present difficulties in their investigation which are far more serious than those which attend the usual synthetical work in organic chemistry. I do not know of any more profitable experience for the advanced student who is already familiar with the principles of organic chemistry and of laboratory practice than the separation in the pure state of the chemical constituents of a plant and the determination of their chemical constitution. In inorganic chemistry the examination of a new mineral furnishes similar experience.

In carrying out research of the kind I am advocating, the chemical investigator will have the additional advantage of knowing that the scientific results he obtains will contribute to the knowledge of the resources of the British Empire, and possibly be the means of laying the foundations of new industries.

I need hardly remind chemists that some of the most important discoveries in our science, and many of those which have had the most profound influence on the development of chemical theory, have arisen from the examination of the constituents of raw materials. The discovery of morphia in opium led to the recognition of the new class of alkaloids; the discovery of amygdalin in the bitter almond of the new group of glucosides; the investigation by Liebig and Wöhler of the chemical properties and composition of the essential oil of the bitter almond was largely instrumental in laying the foundations of modern organic chemistry; whilst it was during the examination of the constituents of bran that Fownes was led to the discovery of furfural and the subsequent recognition of a new type of organic compound. In more recent times the examination of the constituents of oil of turpentine and various essential oils yielded by different plants has been the means of elucidating the chemical theory of the great group of terpenes, and latterly Harries' investigation of caoutchouc has led to the discovery of the ozonides which seem likely to be of much importance as a new means of determining the constitution of certain classes of organic compounds. Lastly, I may remind you that the discovery of helium might have been long delayed had not Professor Miers drawn Sir William Ramsay's attention to the so-called nitrogen furnished by the mineral cleveite.

I have thought that it would be of interest on the present occasion if some account were given in the Section of the chemistry of certain of the raw materials employed in the principal manufacturing industries of the city of York. These industries are vitally concerned with an adequate supply of certain raw products of tropical origin, especially cocoa and gums. In connection with the first of these, which has hitherto been obtained chiefly from the West Indies, a new industry of cocoa production has sprung up in West Africa, notably in the Gold Coast and in Lagos. This West African cocoa presents some peculiarities which have rendered it desirable to examine the nature of its constituents. Gums of the nature of

gum arabic are at present chiefly derived from the French Colony of Senegal. It is, however, clear from the examination of gum collected in West Africa that that country, and especially Northern Nigeria, will be able in the future to contribute to the needs of the British manufacturer, in addition to the Sudan, India, and Australia, which will also be able to make important contributions. In connection with the investigation of these gums derived from new sources at the Imperial Institute, the very remarkable observation has been made that certain gums from India and the Colonies possess the property of evolving acetic acid when exposed to the air. The chemical constitution of one of these gums has been fully investigated at the Imperial Institute by Mr. H. H. Robinson, who will contribute a paper on the subject to the Section, in which he will show that the production of acetic acid is due to the elimination of an acetyl group by hydrolysis through the moisture of the air. He has also succeeded in elucidating to a large extent the chemical nature of the gum. Mr. Robinson will also make a report on the present position of the chemistry of gums, a class of substances whose constitution is exceptionally difficult to unravel. Little, if any, advance has been made in recent years on the well-known researches of O'Sullivan.

There is no more important group of questions demanding attention from the chemist at the present time than those connected with the production of indiarubber or caoutchouc. An enormous increase in the demand for indiarubber has taken place in the last few years, and last year the production was not less than 60,000 tons. Until recently the supply of rubber came chiefly from two sources—the forests of Brazil, which contain the tree known as *Hevea brasiliensis*, furnishing the Para rubber of commerce which commands the highest price, and the forests of Africa, where climbing plants, generally of the *Landolphia* class, also furnish rubber. The increased demand for caoutchouc has led to the extensive planting of the Para rubber tree, especially in Ceylon and in the Federated Malay States. Systematic cultivation and improved methods of preparation are responsible for the fact that the product of the cultivated tree, which begins to furnish satisfactory rubber when six or seven years old, is now commanding a higher price than the product of the wild tree in Brazil. It is estimated that within the next seven years the exports of cultivated indiarubber from Ceylon and the Federated Malay States will reach between ten and fifteen million pounds annually, and that after fifteen years they may exceed the exports of the so-called wild rubber from Brazil.

The services which chemistry can render to the elucidation of the problems of rubber production and utilisation are very numerous. Methods of treatment depending on a knowledge of the other constituents of the latex have led to the production of rubber in a purer condition. Much still remains to be elucidated by chemical means as to the nature of the remarkable coagulation of the latex. As is well known, the latex is a watery fluid resembling milk in appearance which contains the rubber, or, as I think more probable, the immediate precursor of rubber, together with proteids and other minor constituents. The constituent furnishing rubber is in suspension, and rises like cream when the latex is at rest. On the addition of an acid, or sometimes of alkali, or even on mere exposure, coagulation takes place and the rubber separates as a solid, the other constituents for the most part remaining dissolved in the aqueous liquid or 'serum.' The first view taken of the nature of the coagulation process was that, like the coagulation of milk by acids, it is dependent upon a process of proteid coagulation, the separated proteids carrying down the rubber during precipitation.

This explanation cannot, however, be considered complete by the chemist, and there are peculiarities connected with the coagulation of the latex which are opposed to the view that it is wholly explained by the coagulation of the associated proteids. The experimental investigation of the question on the chemical side is beset with many difficulties which are increased if access cannot be had to fresh latex. A number of experiments were made at the Imperial Institute with latex forwarded from India. The difficulties contended with in preventing coagulation during transit were great, but in the case of the latex derived from certain plants these were to some extent surmounted, and the results obtained, especially with reference to the behaviour of certain solvents

towards the latex, led to the conclusion that 'coagulation' can take place after removal of the proteids, and that in all probability it is the result of the polymerisation of a liquid which is held in suspension in the latex and on polymerisation changes into the solid colloid which we know as caoutchouc. Weber, by experiments conducted in South America with fresh latex, arrived at a similar conclusion, which later workers have confirmed. Although the nature of the process is not yet completely elucidated, there is little room for doubt that the coagulation is due to the 'condensation' or polymerisation of a liquid contained in the latex. For the chemist the important question remains as to the nature of this liquid from which caoutchouc is formed.

The chemical nature of caoutchouc is a subject which has attracted the attention of distinguished chemists from the middle of the eighteenth century, among them being Faraday, Liebig, and Dalton. Faraday was the first to examine the constituents of the latex of *Hevea brasiliensis*. It is only in recent years that our knowledge of the constitution of organic compounds, and especially of the terpene group, has rendered it possible to make any great advance. It is interesting to record that Greville Williams, in 1860, made most important contributions to this subject. He identified a new hydrocarbon, isoprene, as a decomposition product of caoutchouc, and recognised its polymeric relation to caoutchouc.

The results obtained from the analytical side, and especially the formation of di-pentene and isoprene by pyrogenic decomposition of caoutchouc, had pointed to the fact that caoutchouc was essentially a terpenoid polymer of the formula $C_{10}H_{16}$. Harries finds, however, that the ozonide of caoutchouc, when distilled with steam, breaks up into lævulinic aldehyde, lævulinic acid, and hydrogen peroxide, and he concludes from this that caoutchouc is a polymer of an 1:5 dimethyl cyclo octadiene. Whilst Harries' work has brought us much nearer the goal, and has led to the discovery of a new method of investigation through the ozonides, which is obviously of wide application, it cannot yet be said that the constitution of caoutchouc has been settled or its relation to the parent liquid substance of the latex definitely established. It has still to be shown how a closed-chain hydrocarbon such as Harries' octadien can undergo polymerisation forming the colloid caoutchouc.

There are strong arguments for the view that the constitution of the parent substance present in the latex is nearly related to that of isoprene. This remarkable hydrocarbon of the formula C_5H_8 , first obtained by Greville Williams from the dry distillation of rubber, is an unsaturated olefenic hydrocarbon which is found among the products, resulting from heating caoutchouc. It readily polymerises forming di-pentene. Bouchardat noticed that this hydrocarbon obtained from the pyrogenic decomposition of caoutchouc furnished a substance identical with rubber when acted on by hydrochloric acid and under other conditions. To Wallach and also to Tilden is due the further important observation that when isoprene prepared from oil of turpentine is kept for some time, it gradually passes into a substance having all the characteristic properties of caoutchouc.

I have very briefly drawn attention to the present position of our knowledge of the chemistry of caoutchouc in illustration of the interest which attaches to the examination of vegetable products, and also because of the immense importance of the problem from the practical and commercial standpoint. Chemistry in this case holds the premier position in reference to this subject, and to a large extent may be said to hold the key to the future of the rubber industry in all its phases. The discovery of better methods of coagulation, preparation, and purification will be effected through chemical investigation, as will also the determination of the manner of utilising the various other plants which furnish rubber-like latices. That the physical properties of raw rubber, on which its technical value depends, are to be correlated with the chemical composition of the material there can be no doubt. The chemical analysis of raw rubber, as at present conducted, is, however, not always to be taken by itself as a trustworthy criterion of quality, and more refined processes of analysis are now needed. Although the finest

caoutchouc for technical purposes is only yielded by some half-dozen plants, under whose names these varieties of caoutchouc pass, there can scarcely be a doubt that the elastic substance in each case possesses a very similar, if not identical, chemical structure. Nearly all the latices and similar fluids furnished by plants contain more or less caoutchouc. Even opium, which is the dried juice of the capsule of the poppy, contains caoutchouc, whilst the opium yielded by certain Indian species contains a notable proportion. Chemistry must determine the means by which caoutchouc can best be separated from these relatively poor latices. In view of the increasing production of the nearly pure caoutchouc which is furnished by *Hevea brasiliensis*, *Funtumia elastica*, *Castilloa elastica*, *Ficus elastica*, and a few other plants which occur or can be cultivated in several of our tropical Possessions, the question is not a pressing one at the moment.

Moreover, it cannot be doubted that chemical science will sooner or later be able to take a definite step towards the production of rubber by artificial means.

The production of caoutchouc by chemical means has, indeed, virtually been accomplished in its formation from isoprene. The exact nature of this change has still to be determined. When this has been done it will only remain to cheapen the cost of production to make the manufacture of synthetic rubber a purely practical problem. I should be the last to discourage the great extension of rubber planting which is now taking place. It is warranted by the present demand for the material. It has also to be remembered that the actual cost of producing cultivated raw rubber, which is at present about one shilling per pound, will probably be reduced, and the market price of rubber may eventually be so considerably lowered that, as with quinine, the synthetic production could not be profitably carried on. That is a question which involves many factors at present unknown, and only time can decide. Chemists may, however, confidently predict that before the British Association again meets at York the synthetic production of rubber will be a fully accomplished fact.

As I have said, our science is concerned with nearly every problem connected with the great rubber industry, and in concluding these few remarks I may allude to the production of vulcanised rubber depending on the formation of additive compounds of the hydrocarbon with sulphur. In this connection I should mention the recent experiments of Mr. Bamber in Ceylon, which appear to show that vulcanisation may be accomplished by acting on the uncoagulated latex with chloride of sulphur. If this proves to be practicable, it may mean the transference to the tropics of the subsidiary industry of vulcanisation, which is at present carried on in Europe.

Owing to the importance and interest which attach to the chemistry of rubber, it is to form an important feature in the work of this Section at the York Meeting. Papers will be contributed by some of the best known workers in this field, by Professor Tilden, and by Professor Harries, of Kiel, who will give an account of his recent work; whilst Mr. Pickles, of the Imperial Institute, will present a report summarising the whole of our chemical knowledge of the subject.

The chemical investigation of raw materials often raises, unexpectedly, problems of great scientific interest. The examination at the Imperial Institute of the seeds of the Para rubber tree (*Hevea brasiliensis*) has shown that they contain what proves to be a valuable drying oil, and in the course of the investigation it was ascertained that there is also present in the seeds an enzyme closely allied to, if not identical with, lipase, which is capable of splitting the oil by hydrolysis into glycerin and the free fatty acid. Subsequently, during the examination of other oil seeds similar enzymes have been detected, and it would appear probable that most oil seeds may prove to contain an enzyme capable of decomposing the fatty constituent.

Another subject of great chemical interest and botanical importance which has come into prominence in connection with the Indian and Colonial work of the Imperial Institute is to be included in a joint discussion which has been arranged with the Section of Botany. I refer to the production of prussic acid by plants which, as I have elsewhere suggested, it is convenient to refer to as 'cyanogenesis.'

In this discussion we shall have the advantage of the co-operation of Professor Van Romburgh of Utrecht and Dr. Greshoff of Haarlem, whose work with Dr. Treub of Java on this subject is known to chemists and botanists alike. The history of the origin of the several investigations in which Dr. Henry has been associated with me is not without interest in connection with the principal subject of this Address. During the first British expedition to the Sudan against the Mahdi a number of transport animals were poisoned through eating a small vetch which springs up in the Nile Valley during the fall of the river. The plant (*Lotus arabicus*) is well known to the Arabs, by whom it is cut when fully grown, and used as fodder for animals.

The results of the investigation of this matter which were communicated to the Royal Society proved that the young plant generated prussic acid when crushed with water. It was found to contain a new glucoside lotusin, together with an enzyme capable of decomposing it into prussic acid, dextrose, and a yellow colouring matter, lotoflavin.

The glucoside is of special chemical interest, as being the only one known which contains the cyanogen group attached in the molecule to the sugar residue. Further investigation has shown that other fodder plants which are occasionally poisonous owe this character to the existence of other cyanogenetic glucosides. In a series of papers communicated to the Royal Society, Dr. Henry and I have described the properties and constitution of dhurrin from *Sorghum vulgare*, and of phaseolunatin, which we have shown to be responsible for the production of prussic acid by *Phaseolus lunatus* (Lima beans), *Manihot utilissima* (cassava or tapioca), and by linseed (the flax plant). Phaseolunatin is remarkable in furnishing acetone as one of its products of hydrolysis. This investigation, besides fulfilling the primary purpose for which it was carried out, has raised a host of problems;—as to the constitution of glucosides, the nature of the enzymes which accompany them in the plants, and also in relation to the fundamental question of plant metabolism.

Another subject of Imperial as well as National importance is to be the subject of a joint discussion with the Section of Physiology. I refer to the problem of diet. As chemists we are interested in this subject chiefly from the point of view of the composition of foods, and of the molecular structure which is associated with dietetic value. The first attempt to deal with the matter from the scientific side was made by a great chemist, Liebig. We are now in a position to investigate the problem more minutely, and the work of American physiologists has already led to important results. We have still to learn how materials such as rice and potatoes, which are nearly free from proteids, continue nevertheless to serve as the main diet of large numbers of people. It would seem that the best plan of operations will be for physiologists to settle by the accurate methods now available the precise value of typical foodstuffs, and for the chemist to deal with these in relation to their composition, and finally with reference to the constitution of their constituents. The time has come when an advance must be made from the chemical side in the analytical methods employed for gauging the value of food materials.

I feel that I have said much, but that I have left still more unsaid on many topics. I must leave almost untouched the entire subject of mineral chemistry, which is not only important in connection with the determination of the resources of India and the Colonies, but is also a subject somewhat neglected on its chemical side, which has been recently brought into prominence through the discovery of radio-activity.

The new radio-active mineral thorianite, from Ceylon, of which Mr. Blake and I have given an account to the Royal Society, brings me at once to a subject which raises the most fundamental of chemical questions, the nature of the elements and of the atom. The recent discussions of this subject have become so purely speculative that, whilst chemistry is bound to follow the lead of physics in this matter, chemists are inclined to consider that more well-ascertained facts are needed for any further discussion to be profitable from the purely chemical side.

In this Address I have ventured to urge the fuller recognition by Government of the scientific method as a powerful instrument in promoting the commercial

development of the Colonies, and I have drawn attention to the important part the science of chemistry can play in the Imperial work of developing the resources of our Possessions.

No apology is needed in this place for directing attention to a subject which involves a most important practical application of our science, since one of the principal functions of the British Association is to bring science into close touch with the problems of our national life, and to interest the general public in the application of science to their solution.

I have, however, also shown that many problems of the highest scientific interest arise in connection with the investigation of these economic problems.

The meeting of the British Association coincides this year with the celebration of the Jubilee of the Coal-tar Colour Industry, and we welcome among us a number of distinguished foreign chemists who have come to join in honouring the great chemist Sir William Perkin, to whom the inception of this industry is due. It is fitting that, as President of the Chemical Section, I should refer to this great occasion in my Address, and express for myself, as well as for the chemists here present, the admiration we feel for Sir William Perkin's genius and for the splendid example he has set in his life-long devotion to experimental research, an example from which all of us have profited who have had the good fortune to come into relation with him.

The following Papers and Reports were read :—

1. *The Electrical Discharge in Air and its Commercial Application.*
By SIDNEY LEETHAM and WILLIAM CRAMP.

Since 1904 the authors have been engaged in developing an apparatus for the production of a peculiarly active gas for bleaching and sterilising purposes, discovered by Mr. Sidney Leatham in 1903, and now much used for flour-bleaching. This work has led to a number of investigations on the electrical discharge, and of its effects on air, the results of which were given.

The subject is divided into three sections :—

1. *The construction and application of the apparatus.*—This consists essentially of an alternator, transformer, ozoniser, and spark-box, the latter two being in series on the high-tension side of the transformer. A current of air is caused to pass through these while they are excited, the general result being an extremely active modification of the air supplied.

2. *The electrical phenomena involved.*—This section includes an investigation of the laws which govern the various types of electrical discharge.

3. *The chemical phenomena involved.*—This section includes the results of analyses, &c., of the gases used, together with an account of their action upon the flour.

Lantern slides illustrating the construction of the apparatus and the behaviour of the different types of discharge were shown.

The authors showed that—

- (a) All the types of electric discharge behave similarly, and need similar means for rendering them steady.
- (b) With a properly arranged circuit any desired type of discharge may be obtained, and, by proper regulation, may be caused to pass gradually to any other type.
- (c) The effect of adding to the number of spark-gaps in series is to raise the necessary pressure, but not proportionally. Similarly one spark $\frac{3}{8}$ " long does not require three times the pressure of one spark $\frac{1}{8}$ " long.
- (d) A current of air impinging upon the discharge increases the pressure required, and sets up violent oscillations in the circuit.
- (e) The sharper the points the lower is the required pressure.

The chemical results were :—

- (f) So long as the air resistance is very high, the chief modification in the air is the production of ozone; but with a gradual breakdown of the air resistance oxides of nitrogen are formed, though this change does not appear to depend upon the temperature of the apparatus, as might have been expected.
- (g) The gas yielded is always in a state of ionisation; but the higher the air resistance, the less marked is this ionisation.
- (h) Contrary to the statement of many authorities, ozone and oxides of nitrogen are found to exist side by side without mutual destruction.
- (i) The bleaching action of the gas appears to be due to oxidation.

Biological tests showed clearly the marked sterilisation produced in flour by means of the gas.

The authors in a summary gave the conditions which should be aimed at for economical production of ozone and oxides of nitrogen respectively; suggesting that no very high temperature is necessary for the latter.

2. *The 1 : 3 : 5-hexatrien.* By Professor VAN ROMBURGH.

3. *Report on Dynamic Isomerism.*—See Reports, p. 157.

4. *Report on the Study of Hydro-aromatic Substances.*—See Reports, p. 257.

5. *On the Effects upon the Concentration of a Solution of the Presence of an Excess of Undissolved Salt.* By A. VERNON HARCOURT, F.R.S.

A paper has recently appeared in the Transactions of the Chemical Society on the attractive force of crystals for like molecules in saturated solutions, in which the author gives an account of experiments which lead him to believe in the existence of such a force. The experiments consist in charging pairs of flasks with saturated solutions of various salts, and adding in one case a quantity of the salt which remained undissolved. The flasks were loosely plugged with cotton-wool, and placed in a cellar where they stood for a number of days, after which the concentrations of the two solutions were determined by evaporation over the water bath, or by taking their density. These experiments appearing to be inconclusive, a further experiment on the same point was made by the present author.

A probable source of error in such experiments arises from variations in the temperature of the solutions and evaporation of water. When from either cause crystallisation is taking place, it will proceed more rapidly in presence of a larger quantity of undissolved salt; and if in this phase portions of the two solutions are withdrawn for examination, that which contains the undissolved salt will be found to be the weaker of the two.

To avoid error from this source the author chose sodium chloride, whose solubility varies very little with temperature, as the salt to be tried, and corked the two flasks containing the saturated solution to which had been added (1) a large quantity, (2) a very small quantity, of the pure salt. They were allowed to stand many hours, with occasional inversion, in a large vessel of water in a room of steady temperature.

A portion of each liquid was then removed, weighed, and evaporated to dryness; the residual salt was further heated and then weighed.

(1) 5·9941 grams of solution contained 1·5739 of salt,

(2) 5·9986 " " " " 1·5756 "

giving in both cases ·2626 gram of salt in one gram of solution.

A repetition of this experiment gave in one case ·2623, in the other ·2626.

The effect of the undissolved salt does not appear to be measurable.

6. *The Crystallisation of Gold in the Solid State.*By G. T. BEILBY, *F.R.S.*7. *On the Temperature at which Water Freezes in Sealed Tubes.*By Professor H. A. MIERS, *F.R.S.*, and Miss F. ISAAC.

The authors showed in 1905 that in a cooling supersaturated solution, which is kept stirred while a few crystals are growing in it, the refractive index rises until at a certain temperature it attains a maximum value, and then suddenly falls; at this moment, also, profuse crystallisation takes place; they concluded that this is the temperature of spontaneous crystallisation.

The conclusion is confirmed by the fact that the same solution enclosed in a sealed tube begins to crystallise (in a shower) at precisely this temperature.

The present paper describes similar experiments, sixty-eight in number, made with water contained in sealed tubes which were vigorously and continuously shaken by hand in a bath of brine. The temperature of the brine was reduced by means of a tube coil through which the cold brine from a refrigerating machine was pumped. The brine in the bath was kept thoroughly stirred by a horseshoe-shaped wooden plunger perforated with holes. The rate of fall of temperature was about 2° an hour. Temperatures were read by a thermometer divided to $\frac{1}{10}$ of a degree.

The water in the tubes was either tap-water, or ordinary distilled water, or pure water of conductivity 1.1×10^{-6} . The initial temperature of the brine bath varied from $+9^{\circ}$ to -2° .

The glass used was both ordinary glass-tubing and hard Jena glass. Some of the tubes were made up just before the experiment, some had been made up weeks before.

All the tubes froze between -2° and $-1^{\circ}.6$; the mean for all the experiments being $-1^{\circ}.86$, and for the pure water $-1^{\circ}.9$.

The ice generally appears at the bottom of the tube, grows very rapidly at first in fan-like crystals, and then in a cloudy shower.

The authors conclude that $-1^{\circ}.9$ is the temperature at which, under atmospheric pressure, pure water freezes spontaneously, *i.e.*, in the absence of ice particles.

It is remarkable that this is also the temperature at which supercooled water possesses its maximum refractive index according to Pulfrich.

Friction produced by enclosing glass, or garnet, or galena, or lead in the tubes with the water causes it to crystallise at a higher temperature, up to about $-0^{\circ}.4$.

FRIDAY, AUGUST 3.

The following Papers were read:—

1. *The Chemical Aspects of Cyanogenesis in Plants.*By Professor WYNDHAM DUNSTAN, *F.R.S.*, and Dr. T. A. HENRY.

See Reports, p. 145.

2. *The Distribution of Prussic Acid in the Vegetable Kingdom.*

By Dr. GRESHOFF.—See Reports, p. 138.

3. *Chemical Research in the Dutch East Indies.* By Dr. GRESHOFF.

4. *The Utilisation of Nitrogen in Air by Plants.* By T. JAMIESON, F.I.C.

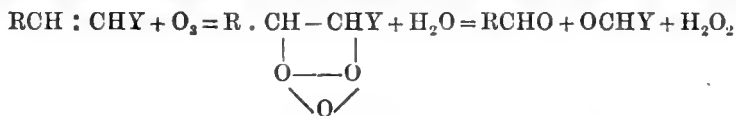
MONDAY, AUGUST 6.

The following Papers were read:—

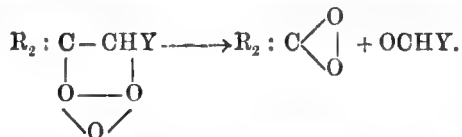
1. *The Present Position of the Chemistry of Rubber.*
By S. S. PICKLES, M.Sc.—See Reports, p. 233.

2. *On the Constitution of Caoutchouc.* By Professor C. D. HARRIES.

If ozonised oxygen is passed into unsaturated hydrocarbons, a molecule of ozone adds itself on at each double bond, and ozonides are formed. These are explosive syrups, and in contact with water are decomposed into aldehydes, or ketones, having smaller molecules, the disruption always taking place at the double bond. At the same time the water which takes part in the reaction is converted into hydrogen peroxide. The process can be expressed as follows:—



Under certain circumstances peroxides also are formed, thus:—

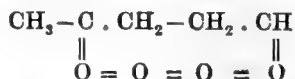


By the application of this process to indiarubber and guttapercha it has been found possible to elucidate with tolerable certainty their chemical nature. The ozonide obtained in the case of rubber has the empirical formula $\text{C}_{10}\text{H}_{16}\text{O}_6$, thus indicating that the molecule $\text{C}_{10}\text{H}_{16}$ contained two double linkages.

The molecular weight of this diozonide was found by the cryoscopic method to be in accordance with the formula $\text{C}_{10}\text{H}_{16}\text{O}_6$. It is thus concluded that the large molecule $(\text{C}_{10}\text{H}_{16})_x$ is broken up into x molecules of $\text{C}_{10}\text{H}_{16}$.



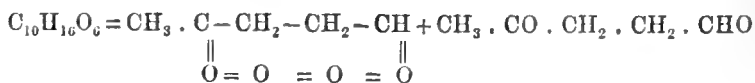
and, according to this conception, indiarubber and guttapercha must be formed by the polymerisation of the hydrocarbon $\text{C}_{10}\text{H}_{16}$. The nature of this hydrocarbon was ascertained as follows: The diozonide was decomposed with hot water or steam, and the products of the decomposition were found to be (1) levulinic aldehyde or levulinic acid, and (2) levulinic aldehyde diperoxide, a crystalline body, $\text{C}_5\text{H}_8\text{O}_4$, having probably the constitution—



On treatment with steam this latter body dissolves completely, passing into levulinic aldehyde or levulinic acid, hydrogen peroxide being formed at the same time. The above-mentioned bodies were found to be the only products of the

decomposition of the diozonide, which can be represented as taking place in two phases.

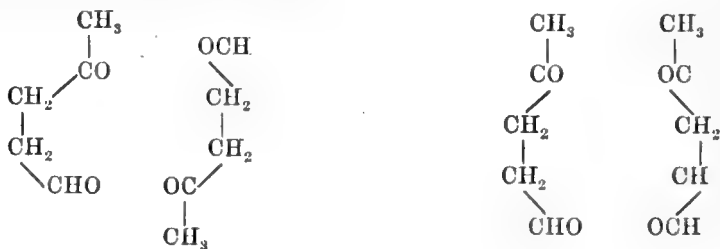
1st phase:—



2nd phase:—

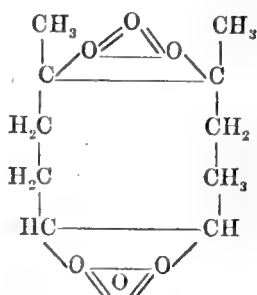
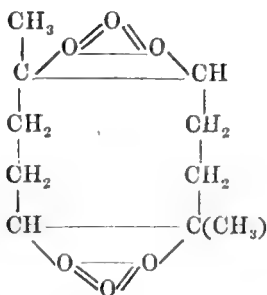


The hydrocarbon $\text{C}_{13}\text{H}_{16}$ must thus contain a cyclic nucleus, the above components having resulted from the ozonide.

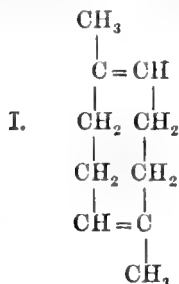


I.
Ozonides

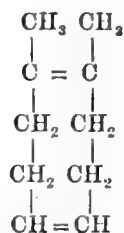
or II.



The hydrocarbon itself must then have the formula—



or II.



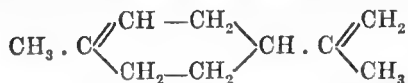
In consideration of the facts that isoprene and dipentene are formed on the distillation of rubber, constitution II. is discarded, as constitution I. alone allows of a simple explanation of these transformations.

The conclusion from this investigation is that the fundamental hydrocarbon in rubber is 1 : 5 dimethyl-cyclo-octadiene (1 : 5). At first sight this is surprising, as the synthetical formation of 8-carbon rings is a matter of great difficulty, only one such compound having been made, viz., azelone. R. Willstätter has, however, recently obtained a cyclo-octadiene from granatoïne and demonstrated its tendency to ready polymerisation. Guttapercha, on treatment with ozone, yielded the same products of decomposition as were obtained in the case of indiarubber,

but the relative quantities of these products varied in the two cases. The explanation may be that the ozonides of indiarubber and guttapercha are not identical but stereoisomeric. Stereoisomerism in the fundamental $C_{10}H_{16}$ hydrocarbon is not possible if the formula proposed is correct, although there is this possibility in the case of the ozonides. Attempts are being made to isolate the dimethyloctadiene, but these have up to the present proved unsuccessful, the solution of the problem being attended with great difficulties.

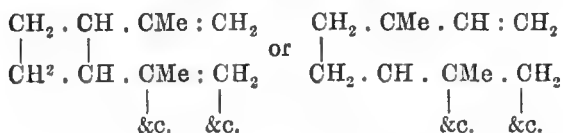
3. On the Polymerisation of Isoprene. By Professor W. A. TILDEN, F.R.S.

Many years ago I showed that the principal terpenes, when decomposed by heat, yield, among other products, a small quantity of isoprene, C_5H_8 . The constitution of this compound has since been shown by Euler¹ to be expressed by the formula $CH_2 : CH . CMe : CH_2$. When kept for a long time isoprene is slowly converted into indiarubber, the process, however, occupying many years. The specimens now exhibited illustrate the process of transformation. If any attempt is made to hasten the operation, as by heat or contact with strong reagents, the greater part of the hydrocarbon is converted into dipentene and the mixture of viscid compounds of high boiling-point, known as colophene, which results from the polymerisation of the terpenes. Dipentene has the formula—



and colophene, no doubt, also contains a number of six-membered rings.

It appears probable, therefore, that the slow polymerisation which ultimately results in the production of solid indiarubber is due to a different mode of linkage leading to the formation of long chains. Except on the assumption of a shifting of hydrogen this can only take place on condition of the formation of a series of tetramethylene rings, somewhat in the following manner:—



Indiarubber, though of high molecular weight, is an unsaturated substance, as shown by the fact that it absorbs oxygen from the air, and unites chemically with sulphur and other elements.

4. The Latex of *Dyera costulata*. By Professor W. A. TILDEN, F.R.S.

Early in May last I received from a correspondent in Singapore a sample of the latex of *Dyera costulata* to which a small quantity of ammonia had been added, to keep it from coagulating. It remains a white creamy fluid of specific gravity 1.11, miscible with water. I am without information as to the reaction of the original fluid with test-papers. It is rare to find vegetable juices exhibiting an alkaline reaction, but I am disposed to believe that this latex in the fresh state possesses slight alkalinity, as it is coagulated sooner or later by all acids, without agitation. But, as in milk, the suspended particles unite when the liquid is violently shaken. It is also coagulated by admixture with a strong solution of common salt, and when warmed with an equal volume of 20 per cent. solution of caustic soda. Heated to a temperature of $70^\circ - 80^\circ C.$, solidification does not occur except at the surface, where a skin forms; and even on boiling no immediate change takes place. The milk as received yielded about 44 per cent. of solid by coagulation with

¹ Ber. 1897, 30, 1789.

hydrochloric acid. The aqueous liquid filtered from the coagulum contains a small quantity of a substance which reduces Fehling's solution only after it has been heated for a few minutes with hydrochloric acid. Whether this is cane sugar or a glucoside I have not yet ascertained. The amount of proteid present is very small. The specific gravity is slightly greater than water.

The coagulated solid is tough, but contains only a very small quantity of rubber substance, as it is almost entirely soluble in alcohol and acetone.

Dyera costulata is reputed to be the botanical source of the white gutta now quite familiar under the name of 'Pontianak,' the name of the port in Borneo from which it is sent to Europe. Pontianak contains a small quantity of rubber mixed with two or more substances, of which at least one (m.p. 173°) is crystallisable from alcohol. This, analysed in my laboratory, gave as the mean of several combustions C=81.2 and H=11.0 per cent. This corresponds roughly to a formula $C_{14}H_{22}O$, which requires C=81.5, H=10.7. The molecular weight, 206, required for this is, however, much less than the result of observations of the freezing-point of benzene solutions which gave as a mean 322.

The crystalline substances contained in gutta have been supposed to be related to lupeol, but this can hardly be said to be definitely established. Likiernik¹ found in lupeol C=84.01, H=11.38 and melting-point 204°.

As to the process by which caoutchouc and the associated substances are formed in the latex, nothing seems to be known; but I incline to the view that they are probably formed in the laticiferous vessels by the rupture of molecules of compounds of the nature of tertiary alcohols with the production of water and the hydrocarbon or other substance. The readiness with which terpin splits into terpineol and water by the action of minute quantities of acid is an analogous process.

5. *The Present Position of the Chemistry of the Gums.*

By H. H. ROBINSON, M.A.—See Reports, p. 227.

6. *On a Gum (Cochlospermum Gossypium) which produces Acetic Acid on Exposure to Air.* By H. H. ROBINSON, M.A.

7. *Note on Ergot Alkaloids.* By G. BARGER and F. H. CARR.

The crystalline alkaloid ergotinine was obtained from ergot by Jauret more than thirty years ago, and does not seem to have been studied chemically since then, no doubt owing to its extreme scarcity.

Jauret assigned to ergotinine the formula $C_{70}H_{40}O_{12}N_4$, based on rather scanty analytical data; the molecular weight was deduced by analyses of the amorphous hydrobromide and hydrochloride of very doubtful purity.

We have been able to confirm Jauret's figures for the percentage of carbon and of hydrogen (roughly C=68.5 per cent., H=6.5 per cent.), but find nearly 3 per cent. more nitrogen (11.7 instead of 9 per cent.).²

Molecular weight determinations in phenol solution by the cryoscopic method gave the values 477 and 516; in pyridine solution the value 463 was obtained, employing a microscopic vapour pressure method, devised by one of us.

Without as yet definitely assigning a formula to ergotinine, we suggest that the alkaloid probably has the composition $C_{27}H_{31}O_4N_4 = 475$.

It will be seen that the ergotinine molecule is not more complex than that of several well-known alkaloids, and that it is much smaller than Jauret imagined. It is unique among alkaloids in containing four nitrogen atoms.

¹ *Ber.* 24, 185.

² We used Dumas' method; Jauret worked according to Will and Varentrapp. We are indebted to Dr. P. Haas for two of the determinations, in which he proved the absence of methane in the residual nitrogen gas.

Like Jauret, we have failed to prepare crystalline salts or other derivatives of ergotinine.

Ergotinine apparently contains no phenolic hydroxyl and no methoxy-group. It is probable that there is a methyl group attached to one of the nitrogen atoms. In methyl iodide solution a gelatinous methiodide is formed; and when one molecular proportion of bromine is added in chloroform solution, the hydrobromide of monobromo-ergotinine separates out.

From the ethereal mother liquors of crystalline ergotinine Jauret obtained another non-crystalline alkaloid, which he termed amorphous ergotinine. A similar resinous substance of alkaloidal nature and great physiological activity was described by Kobert as cornutine.

We have now obtained the second alkaloid in a state of chemical purity. Though itself amorphous, it forms a number of crystalline salts. The oxalate crystallises from alcohol in minute plates, mostly arranged in rosettes; the tartrate forms prisms, the phosphate fine needles, frequently grouped in sphaerites.

Unlike ergotinine, the second alkaloid readily dissolves in aqueous caustic soda, and gives a benzoyl derivative by the Schotten-Baumann method. It probably contains a phenolic hydroxyl group.

The analytical data so far obtained point to a formula differing but slightly from that of ergotinine; and as both alkaloids occur in the same plant it is probable that they are closely related chemically (as are, for instance, quinine and cinchonine).

Both alkaloids give strongly fluorescent solutions, and both give with sulphuric acid and ferric chloride the play of colours originally described by Keller as characteristic of ergotinine.

According to the physiological experiments of Mr. H. H. Dale, the amorphous alkaloid produces in doses of a few milligrams all the typical effects of ergot described by him in a recent paper.¹ There seems little doubt that it is the most important, if not the one essential, active principle; whereas pure crystalline ergotinine is physiologically almost or quite inactive.

8. *The Hydrolysis of Sugars.* By R. J. CALDWELL, B.Sc.
See Reports, p. 267.

TUESDAY, AUGUST 7.

Joint Discussion with Section I (Physiology) on the Factors which determine Minimal Diet Values.

The following Papers and Reports were read:—

1. *The Absorption of Ammonium Salt by Clay and other Soil Constituents.* By A. D. HALL and C. T. GIMINGHAM.

The continuous application of ammonium chloride and sulphate to certain of the experimental plots of Rothamsted has resulted in the production of an acid reaction in the soil. To ascertain the cause of this the action of ammonium salts upon various soil constituents in a pure state has been reinvestigated. Dilute solutions of the salts were shaken with the materials in question for twenty-four hours, which time was found more than sufficient to complete the reaction. With silica there is no action. With kaolin, pure clay, and peats of various origin the reaction is always one of substitution, ammonium going out of solution and being replaced by equivalent amounts of calcium and magnesium, &c.

No measurable amount of absorption takes place, nor is there any development of an acid reaction. Experiments with pure ground natrolite showed that the

¹ *Journal of Physiology*, 1906, vol. xxxiv., p. 163.

reacting substances in the clays must be of a kindred nature—zeolitic double silicates.

The absorption of ammonium salts by soils must be due chiefly to such double silicates, for the character of the reaction is but little affected by the presence of calcium carbonate.

It is found that when the clay is in excess the reaction between it and ammonium chloride can be expressed by the equation—

$$\frac{Ka(\text{Ammonium absorbed by clay})^2}{\text{Final concentration of solution in ammonium}}$$

When the solution is in excess the amount of ammonium absorbed is proportional to the strength of the solution. Curves have been constructed showing the variation of the absorption with the strength of the solution for various ammonium salts, potassium and barium chlorides, and hydrochloric acid.

2. *Oxidation in Soils and its Relation to Productiveness.* By FRANCIS V. DARBISHIRE, B.A., Ph.D., and EDWARD J. RUSSELL, D.Sc.

All soils possess the power of absorbing oxygen—some to a marked extent. The authors have devised an apparatus for measuring the rate of absorption, and have studied the influence of various factors, and also the connection with the productiveness of the soil.

It has been found that oxidation is mainly, but not entirely, due to the activity of micro-organisms; oxidation still goes on in soil sterilised at 120° C., or by treatment with 1 per cent. mercuric chloride; but the rate is only about one-fifth of what it was.

The rate of oxidation does not entirely depend on the amount of organic matter present in the soil. Moisture is essential; as its amount increases the rate of oxidation also increases until near the point at which the soil becomes waterlogged. The addition of calcium carbonate, or of sugar, increases the rate: in the latter case the maximum increase occurs with 1 per cent. of sugar. Small quantities of poisons like mercuric chloride, thymol, copper sulphate, &c., also increase the rate till the optimum amount, .01 per cent., is reached. Further quantities reduce the rate considerably.

Somewhat different results were obtained with partially sterilised soils. If a soil is exposed to vapours of chloroform, carbon disulphide, or toluene, and the antiseptic then removed in a current of air, the rate of oxidation markedly increases. A similar result is obtained when the soil has been exposed to sunlight or to a temperature of 85° C., insufficient to kill spores.

The rate of oxidation is closely parallel to the productiveness of the soil. For a series of similar soils of which the cropping power is known it is found that the most productive has the highest rate of oxidation, and that the others follow in the same order for both properties. The parallelism holds, not only for soils in the natural state, but also, with certain limitations, for soils which have been artificially treated. Thus partial sterilisation by heating to 95° increases the rate of oxidation, and also increases the productiveness; treatment with volatile antiseptics has the same result. It is essential, however, that the soil conditions should be aerobic, as in arable soils; pasture soils, where the conditions are less perfectly aerobic, do not follow the general rule. In view of this difference the authors suggest that the rate of oxidation affords a measure of the bacterial activity, which is closely connected with productiveness.

3. *A Method of Determining Indigotin.* By W. POPPLEWELL BLOXAM.

The author was employed in India during the years 1902–1904 in research work on plant indigo, and during the year 1905 publication was made of the results obtained—‘An Account of the Research Work in Indigo, carried out at

Dalsingh Terai Research Station (under subsidy of the Government of Bengal) from 1903 to March 1904,' by W. P. Bloxam and H. M. Leake, with the assistance of R. S. Finlow (Calcutta : The Bengal Secretariat Book Depot, 1905).¹

In the Report to the Government of Bengal the author expressed the opinion that no further progress was possible in the chemistry of plant indigo until an accurate process was available for the estimation of indigotin (*a*) in the pure state, (*b*) in the green leaf, (*c*) in the crude cake.

In October 1905 the author was appointed by the Government of India to continue this work in the Clothworkers' Research Laboratory of the University of Leeds, under the general supervision of Mr. A. G. Perkin, F.R.S.

A revision of the methods previously proposed for analysis of pure indigotin and of crude indigo was first attempted.

1. The original method of Mohr² involved sulphonation and subsequent titration with permanganate. To avoid the excessive consumption observed, due to interaction of the impurities present, modification of this process had been proposed by Rawson and by Grossmann. The former first proposed salting-out the sulphonation product with sodium chloride, resolution and titration. Later Rawson proposed removal of the impurities by the addition of solution of barium chloride, and subsequent titration of the clarified sulphonate.

Grossmann³ states that Rawson's process is unsatisfactory, and claims that a satisfactory purification is effected by treating the sulphonation product of a crude indigo with calcium carbonate, and making a titration of the clear liquid after subsidence of the precipitate.

A prolonged and careful examination of these methods proved them to be inaccurate; for either (*a*) a loss of indigotin was experienced, it being carried down by the precipitate designed to purify the solution, or (*b*) the impurities were not removed.

Next followed a study of the process of sulphonation and the preparation of the following salts: Potassium indigotinmonosulphonate, potassium indigotin disulphonate, potassium indigotin trisulphonate, potassium indigotintetrasulphonate.

Investigation was then made of the conditions under which the sulphonation of pure indigotin could be effected without loss. It was found that, contrary to existing statements,⁴ that fuming sulphuric acid could be employed for sulphonation without involving destruction of indigotin. Thus pure indigotin could be heated to 98° C. for three-quarters of an hour in a water oven, with 20 per cent. fuming acid, without loss of indigotin. For crude cake indigo the acid used must be 5 to 10 per cent. stronger in order to attain the same degree of sulphonation.

It now became clear that the processes recommended by Rawson and Grossmann failed because the degree of sulphonation attained was too low. In consequence, on addition of salts of barium or calcium the difficultly soluble disulphonates were thrown down with the impurities, thus escaping estimation.

As, however, addition of calcium carbonate did not produce precipitation with solutions of the tri- and tetra-sulphonic acids when added at Grossmann's prescribed concentration (1 : 1000), it seemed possible to use Grossmann's prescription at the higher degrees of sulphonation.

But here a new difficulty arose; for although on sulphonating crude cake indigos to the stage of tri- or tetra-sulphonic acids, addition of calcium carbonate gave no precipitation of the blue calcium disulphonate, little of the impurity was removed. The conclusions previously drawn regarding these processes were thus confirmed, and the processes were abandoned.

2. Examination was now made of the method proposed by Knecht for the estimation of indigotin by means of titanium trichloride.⁵

¹ 'Our Present Knowledge of the Chemistry of Indigo,' by W. P. Bloxam, *Chem Soc. Trans.*, 1905, 87, p. 975.

² *Dingl. polytech. Journ.*, vol. cxxxii., p. 363.

³ *Journ. Soc. Chem. Ind.*, 1905, p. 308.

⁴ Wangerin and Vorländer, *Zeits. f. Farben- und Textilchemie*, 1902, vol. i., p. 281.

⁵ *Journ. Soc. Dyers and Col.*, 1903, pp. 66, 169; 1904, p. 97; 1905, p. 292.

The process as recommended for the estimation of pure indigotin did not prove satisfactory. But as a result of experiments made, it was found that the following points must be attended to to insure quantitative results:—

- (a) The strengths of the two solutions must be adjusted.
- (b) Certain relations must exist between the tartaric and mineral acids present.

Under these conditions titanium trichloride can be safely used as an adjunct to the new analytical process described below.

Knecht, however, claimed further that in the case of crude indigo, by employing Grossmann's treatment with calcium carbonate he could use titanium trichloride with success. But in view of the present results Knecht's claim cannot be sustained.

The Potassium Tetrasulphonate Process for the Estimation of Indigotin.

A new process of analysis was now evolved on the following lines: In the case of pure indigotin it was found that if sulphonation was effected with 20 per cent. fuming sulphuric acid, the mixture being heated for forty-five minutes at 98° C., the product was indigotintetrasulphonic acid. And that this solution, at a suitable dilution, yielded, on the addition of solution of potassium acetate, the whole of its indigotin as crystalline potassium indigotintetrasulphonate. This precipitate was filtered off and redissolved in water to a definite volume. On this solution estimations could be made of the indigotin, with quantitative accuracy, by titration with—

- (a) Solution of potassium permanganate;
- (b) Solution of titanium trichloride, employing the precautions previously stated.

Furthermore, with suitable modification of the mode of sulphonation, the process could be applied to the estimation of indigotin in crude cake indigo.

For it was found that the impurities of the crude cake were, after sulphonation, more soluble than indigotintetrasulphonate, thus permitting the quantitative separation of all indigotin as the potassium tetrasulphonate, whilst the concentration of potassium acetate was too low to determine the precipitation of the impurities.

As a proof of the accuracy of the potassium tetrasulphonate process two considerations are advanced:—

(a) After separating the potassium tetrasulphonate from the sulphonation product of a crude indigo it yielded on titration with both potassium permanganate and titanium trichloride an end-point identical with that observed when pure indigotin is similarly treated.

(b) Pure indigotin was mixed with known weights of the brown impurities of cake indigo (these having been extracted from crude Bengal cake by the action of pyridine and dried at 140° C.); on sulphonating these mixtures and separating the indigotin as potassium tetrasulphonate, the indigotin percentage obtained on titration was precisely that of the mixture made.

In the report on the work done for the Government of Bengal at Dalsingh Teraï the author expressed the opinion that the 'efficiency' of the present method of indigo manufacture was very low.¹

As the result of a large number of analyses now made, employing the potassium tetrasulphonate method, of the finished cake produced by the Pemberandah factory during the season 1903-1904, the author's prediction was verified.

For it was found that if the indigotin content for the whole green plant (ordinary Indian varieties) be taken, as seems reasonable, at 0.6 per cent., then the highest efficiency attained during careful manufacture does not reach 50 per cent. of the total indigotin obtainable, whilst the average efficiency of the whole

¹ *Loc. cit.*, Section II., p. 7.

season is 25 per cent., falling thence to 12·6 per cent. The attention of the Government of India will be called to this wasteful method of manufacture, with a view to the long-needed improvements being introduced to India without delay.

4. *Report on the Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives.*—See Reports, p. 159.

 5. *Report on Wave-length Tables of the Spectra of the Elements and Compounds.*—See Reports, p. 161.
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SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION.—G. W. LAMPLUGH, F.R.S., F.G.S.

 THURSDAY, AUGUST 2.

The President delivered the following Address :—

ON BRITISH DRIFTS AND THE INTERGLACIAL PROBLEM]

IF a personal reminiscence be pardonable, let me first recall that twenty-five years ago, at a meeting of this Section in this same room, I ventured, while still a youth, to contribute my mite towards the right understanding of the Yorkshire drifts. The occasion will always remain memorable to me, for it was my first introduction to a scientific audience, and the encouraging words spoken by Ramsay from this chair impressed themselves upon me and gave me confidence to persevere in the path of investigation.

Finding myself again in these surroundings, it seems fitting that with fuller experience and less diffidence I should resume the subject by bringing before you some further results of my study of the drifts. But it is with just a sigh that I recollect how on the former occasion I was able to reach a definite conclusion on a simple problem from direct observation, and had confidence that all problems might be solved by the same method; whereas now I find confronting me an intractable mass of facts and opinions, of my own and other people, terribly entangled, out of which it seems to grow ever more difficult to extract the true interpretation.

That the glacial deposits possess some quality peculiarly stimulating to the imagination will, I am sure, be recognised by everyone who has acquaintance with glacialists or with glacial literature. The diversity and strongly localised characters of these deposits, together with their aspect of superficial simplicity, offer boundless opportunity to the ingenious interpreter; and therefore it is not surprising that along with the rapid accumulation of facts relating to bygone glaciation there should have arisen much divergent opinion on questions of interpretation. Nor need we regret this result, since these differences of opinion have again and again afforded the stimulus for research that would not otherwise have been undertaken.

The Interglacial Problem.

One of the most important points on which there has been, and still is, wide difference of opinion among glacial geologists, both in this country and abroad,

is with regard to the value of the evidence for interglacial periods; and it will be my aim, in bringing before you some general conclusions regarding the drifts, to concentrate attention principally upon this evidence.

To keep the discussion within practicable limits I must perforce assume the former extension of ice-fields over the glaciated areas; for although I know that there are still dissentients from this fundamental proposition, the cumulative evidence in its favour has been so frequently recapitulated that it would not be justifiable for me to detain you by repeating the arguments.

It is now, I think, agreed by all who accept this proposition that the ice-sheets of the Glacial Period, though of vast extent, had their northern as well as their southern limits; the original idea, that they represented the outer portion of a polar ice-cap, having been disproved by more extended researches in the more northerly part of our hemisphere. Moreover, it has been found that these ice-sheets had their origin in the coalescence of masses which spread outward from separate areas of accumulation, acting more or less independently, so that the individual sheets did not all attain their farthest bounds at the same time. But this recognition of independent centres of glaciation has given sharper prominence to the question whether the glacial deposits are to be regarded as the product of a single epoch of glaciation, or whether they represent successive epochs of this kind, separated by intervals during which the great ice-sheets temporarily vanished.

As opinion stands at present, probably most geologists lean to the idea that the glaciation was interrupted by at least one interglacial epoch, during which the climate of any particular latitude became not less warm, and perhaps warmer, than it now is. This is the Interglacial hypothesis in its simplest form. But it has been frequently pointed out that the criteria depended upon in the recognition of warm interglacial conditions cannot be all assigned to the same horizon, since they recur at different positions in the drift series. Hence it has been claimed that two, three, four, or even five interglacial epochs, with a corresponding number of separate epochs of glaciation, may be recognised in the glacial sequence. In respect to the number, relative importance, and correlation of these epochs or stages in different countries, or in different parts of the same country, there has been, however, no pretence to agreement among the upholders of the Interglacial idea.

In opposition to these views of every degree, a smaller number of glacialists have urged that there is no proof of even a single absolute interruption of the glacial conditions from the beginning to the end of the period; and that the evidence indicates only one great glaciation, during which there were wide oscillations of the margins of the ice-sheets in different places, due probably to more or less local circumstances.

This radical difference of interpretation respecting the constitution of the Glacial Period assumes the greater consequence in that it bears directly upon many questions other than those which are strictly geological. Thus, the antecedents and distribution of our present fauna and flora, and the time and conditions of that momentous event, the appearance of man in Northern Europe, are deeply involved in the issue.

Moreover, until we can tell whether it is one or several periods of glaciation that we require, how can we approach the other sciences for aid in our search for the cause of the Ice Age? It is, indeed, essential that, before seeking counsel's opinion of this kind, the geologist should have all his evidence at command and well-marshalled, so that he can say such and such are the facts, and this the order of them. Otherwise he may receive, not the desired interpretation, but advice as to what he ought to have found and instructions to go and find it. And that such instructions may be detrimental rather than helpful to our progress is, I think, shown by the history of the Interglacial hypothesis. In this matter the glacial geologists, having some evidence for the alternate extension and recession of ancient glaciers, fell readily under the influence of the fascinating theory brought forward by James Croll to explain the Great Ice Age, whose interpretation, however, reached far beyond the facts that were placed before him.

I need hardly remind you that, according to Croll, a sufficient explanation of the Glacial Period could be found in certain astronomical conditions, which were shown by his calculations to have recurred at definite intervals, and were supposed to have produced repeated alternations of cold and warm climate at the opposite hemispheres during the course of the period. It is not my purpose to discuss this or any other theory regarding the cause of the Great Ice Age, but only to direct your attention to the influence of Croll's views upon the work of observation. If the theory could have been sustained, it would have given into the hands of the geologist a first instalment of that absolute measure of geological time which he so ardently desires; and with this allurements it is no wonder that the theory was welcomed and hopefully put to the test. Foremost among its exponents was Professor James Geikie; and we must all recognise that its main importance to the field-geologist arose from his powerful support and masterly arrangement of the evidence favourable to the hypothesis.

It is not surprising that, amid the complicated mass of facts confronting us in the glacial deposits and among the voluminous literature wherein these facts are more or less skilfully enwrapped, there should have been found some material to support the idea of a recurrent succession of glacial and interglacial stages. But the glamour of the astronomical hypothesis has waned, and it is recognised that there are flaws in the physical aspect of the theory and in its geological application that render it untrustworthy. I think, therefore, that the time has come when we should reconsider the matter in critical mood, uninfluenced by the early glow of the theory, after the wise example of that ancient people who debated all matters of import in two opposite frames of mind.

On the present occasion it would be impossible adequately to discuss the whole subject, and I propose to deal principally with my own experience in attempting to apply the Interglacial hypothesis to my field-work. I hope also to be able briefly to review the evidence from other parts of our islands in the light of this experience.

And here I may remind you of the important part which this Section of the British Association has taken in the study of the subject by organising Committees of Research, provided with funds for carrying out excavation and other necessary work. During the twenty-five years since we last met at York I find that, including the work in certain bone-caves, there have been fourteen such committees; and in many cases their operations have extended over several years, so that over thirty separate reports have been published in the Annual Reports of the Association.¹ The precise information embodied in these reports is of high scientific value, and I am sure that these results are very creditable to the Section.

Classification of the Drifts.

I have mentioned the influence of Professor J. Geikie in the establishment of the Interglacial hypothesis; and before proceeding further it is necessary that we should recapitulate the scheme of classification which he has proposed for the drifts on the basis of this hypothesis. This elaborate scheme has been built up by a skilful combination of evidence gleaned from various parts of Europe, and represents the hypothesis in its extreme form. Stated in downward succession it stands, in its latest development,² as follows:—

¹ Viz., Reports on 'Raygill Fissure' (1883-1886); 'Manure Gravels of Wexford,' &c. (1887-1890); 'Welsh Caves' (1886 and 1898); 'Sewerby Raised Beach' (1888-1890); 'Elbolton Cave' (1891-1894); 'Scottish Marine Drifts' (1893-1896); 'Calf Hole, Skipton' (1894); 'Hoxne Plant Beds' (1896); 'Irish Elk in the Isle of Man' (1897-1900); 'Pleistocene Beds near Toronto' (1898-1900); 'Moel Tryfaen Drift' (1898); 'Uphill Cave' (1899-1901); 'Irish Caves' (1901-1904); 'Kirmington and other Fossiliferous Drifts' (1903-1905). During the same period there have also been twenty-three reports of the 'Erratic Blocks' Committee, which bear indirectly upon the problem.

² 'The Classification of European Glacial Deposits.' *Journ. Geol.* (Chicago), vol. iii, (1895), pp. 241-269.

EUROPEAN GLACIAL AND INTERGLACIAL STAGES (Professor J. GEIKIE).

XI. Upper Turbarian	=	Sixth Glacial Period ¹
X. Upper Forestian	=	Fifth Interglacial Period ¹
IX. Lower Turbarian	=	Fifth Glacial Epoch
VIII. Lower Forestian	=	Fourth Interglacial Epoch
VII. Mecklenburgian	=	Fourth Glacial Epoch
VI. Neudeckian	=	Third Interglacial Epoch
V. Polandian	=	Third Glacial Epoch
IV. Helvetian	=	Second Interglacial Epoch
III. Saxonian	=	Second Glacial Epoch
II. Norfolkian	=	First Interglacial Epoch
I. Scanian	=	First Glacial Epoch.

But although, as already mentioned, the Interglacial hypothesis in its simpler form has many supporters in this country, I do not think that the above scheme in its entirety has yet found any adherents among British glacialists. Usually, when beds supposed to be of interglacial age have been described by other workers, it has been implied that only a single interval of milder conditions was in mind; and even in the exceptional cases where several different boulder-clays separated by sand and gravel have been held to represent as many different epochs of glaciation, it is rare that any attempt has been made, except by Professor Geikie himself, to classify the supposed events in accordance with the scheme. I suppose that most field-workers have felt, like myself, that while some part of the classification might possibly be sustained, this finished arrangement of the admittedly imperfect evidence was too artificial to be accepted with confidence, and that it was inadvisable to allow one's self to be hampered, in an inherently difficult task, with further difficulties that, after all, might, like 'the word Bear-baiting,' be 'carnal and of man's creating.'

On the other hand, partly, no doubt, from the persuasive manner in which its author has presented his case and his courteous readiness to meet objections, but still more from the vast extent of the field drawn upon for the argument, the scheme has aroused less active criticism than it has, in my opinion, deserved. The critic has shrunk from the magnitude of the task of testing it in all its parts, while to pick out the local flaws in any particular part has seemed invidious.

In taking this scheme as the basis of my examination into the evidence, I am aware that the local limitations which I have set myself will be held to impair the validity of my conclusions. But as there is at present in every glaciated country the same confusion of opinion on the Interglacial problem as in our own, and the same discussion upon the fundamental value of the evidence, it appears to me that we can find strong justification for considering our own problem on its separate merits. And the necessity for a re-sifting of the British evidence is the more urgent since it is frequently taken for granted in the discussions abroad that there is a well-established glacial sequence in Britain, which can be called in to support the argument for other lands.

The Interglacial Problem in Other Countries.

It will serve to illustrate the condition of the problem in other countries if I refer briefly to some of the literature which happens to have come under my notice, though I can rarely claim sufficient knowledge of the foreign work to discuss its value.

Norway.—In Norway there appears to be no direct evidence for interglacial epochs, though the existence of one such epoch is supposed to be indicated by a change in the direction of ice-flow, and by the presence of an arctic flora at the base of the Danish peat-mosses which is absent in Norway. By Dr. A. M. Hansen² the superficial deposits are classed as follows:—preglacial: proteroglacial: interglacial: deuteroglacial: and postglacial.

¹ 'Period' in original; *op. cit.*; probably misprints for 'Epoch.'

² A. M. Hansen, 'The Glacial Succession in Norway,' *Journ. Geol.*, vol. ii (1894), pp. 123-144.

Sweden.—In Sweden, and, I believe, also in Denmark, the Interglacial hypothesis is generally accepted, at least to the extent of one epoch of deglaciation, but is strenuously opposed by Dr. N. O. Holst, who states his conviction, based on the result of his observations in Greenland, that the so-called interglacial sands and gravels and the 'upper moraine' of Sweden represent the residual products of the ice-sheet that laid down the 'lower moraine' as a ground-moraine. He also embraced the drifts of North Germany in this explanation.¹

Germany.—In Germany, the discussion on the 'Interglacialismus' is still in active progress. The idea of one interglacial epoch, corresponding to the 'Helvetian' of Professor J. Geikie's scheme, is widely entertained; and some geologists, influenced largely by evidence in the Alps, think that an earlier interglacial stage (= 'Norfolkian'), preceded by a stage of glaciation (= 'Scanian'), may have to be admitted, though the German evidence is acknowledged to be imperfect. But Professor Geikie's interpretation of the North German drifts, on which he seeks to establish the 'Neudeckian Interglacial' and the 'Mecklenburgian Glacial' epochs is strongly and authoritatively opposed. In a searching criticism of these views Dr. K. Keilhack, of the Prussian Geological Survey,² states that no reason has been found, by himself or his colleagues, for the proposed separation of the upper drifts into these separate epochs; and he remarks that, on similar grounds, 'the so-called "last glacial epoch" would have to be divided into four if not five epochs, so that even the most fanatical advocate for as many glacial periods as possible would be terrified.' Professor Geikie, in his reply to this criticism,³ brings forward the British evidence to establish the case in Germany. But, as we shall see, this evidence is especially weak, and we in this country had expected that the stronger proof lay in Germany.

While the supporters of the 'Interglacialismus' are thus uncertain how much of the scheme they will accept, there are other geologists in Germany who repudiate the hypothesis in its entirety, and hold for the 'singleness of the Ice-Age.' Among these I may mention Professor E. Geinitz,⁴ whose vigorous attack has been supported by Dr. W. Wolff, in a useful summary of the discussion, which contains many references to the literature.⁵

Russia.—In Russia, again, opinion is divided, and the evidence brought forward in favour of the Interglacial idea has been adversely criticised by Mr. S. Nikitin, of the Russian Geological Survey,⁶ who considered that, whatever may have been the conditions farther westward, oscillations of the ice-margin would suffice to explain the facts observed in this outer portion of the glaciated area.

The Alps.—In the Alps there appears to be definite evidence for several periods of advance of enormous glaciers from the mountain valleys, with intervening periods of great recession, and these are supposed to correspond to glacial and interglacial epochs in Northern Europe; but there has been much difference of opinion respecting this evidence and its interpretation. By Professors A. Penck and E. Brückner, who have systematically investigated the phenomena, the ice-movements are held to indicate four separate epochs of glaciation, with three, or

¹ 'Har det fannits mera än en istid i Sverige.' *Sveriges Geologiska Undersökning* Ser. C., No. 151 (1895); and 'On the Relations of the "Writing Chalk" of Tullstorp (Sweden) to the Drift Deposits, with Reference to the Interglacial Question.' *Geol. Mag.*, dec. v., vol. i. (1904), pp. 56-59.

² Professor Geikie's Classification of the North European Glacial Deposits. *Journ. Geol.*, vol. v. (1897), pp. 113-125. See also discussion by H. Munthe, 'Studien über ältere Quartärablagerungen im südbaltischen Gebiete.' *Bull. Geol. Instit. Upsala*, vol. iii. No. 5 (1896), pp. 27-114.

³ 'The Last Great Baltic Glacier.' *Journ. Geol.*, vol. v. (1897), pp. 324-339.

⁴ 'Die Einheitlichkeit der quartären Eiszeit.' *Neues Jahrb. f. Mineralogie*, etc., xvi. (1902), pp. 1-98, and other papers.

⁵ 'Zur Kritik der Interglacial-Hypothese.' *Naturwiss. Wochenschrift*. Neue Folge. Bd. ii. No. 26 (1903), 14 pp.

⁶ 'Sur la constitution des dépôts quaternaires en Russie, etc.' *Rep. Congrès Internat. d'Archéologie*, Moscou, 1892.

perhaps four, warm interglacial epochs.¹ Not having yet found an opportunity to make myself sufficiently acquainted with the evidence, I may not fully recognise its importance; but it appears to me that the factors governing the glaciation of this Alpine region may have been very different from those that controlled the lowland glaciation. And although it is certain that the great extension of the Alpine glaciers was due to the same glacial conditions that gave rise to the lowland ice-sheets of Northern Europe, I do not regard it as a necessary consequence that advances and retreats of the ice should occur simultaneously in both regions. Variation in the relative amount of snowfall over the glaciated areas during the course of the Glacial Period, for which there is much evidence, would be likely to produce great effects in the high-lying reservoirs of the Alps; and at the latitude of this region we should expect rapid recession of the low-level glaciers in response to diminished supply. To distinguish between the effects of oscillations in precipitation and of oscillations in temperature under such conditions must be peculiarly difficult.

North America.—In North America, where both the drifts and their literature attain gigantic proportions, the state of opinion is closely analogous to that among ourselves. It is agreed by all that during the Glacial Period there were very extensive oscillations in the borders of the ice-sheets; and by some geologists some of the stages of recession are supposed to represent mild epochs of actual 'deglaciation'; while others, fewer in number, among whom Mr. Warren Upham and Dr. G. F. Wright have been the most active, regard these stages as of minor consequence, and advocate the essential unity of the glaciation. And between the two extremes stand the great majority of the workers in American glacial geology, who refrain from expressing positive opinions, but mostly lean toward the idea of at least one great interruption in the glaciation. Some of the suggested schemes of classification² are fully as elaborate and complex as that proposed for Europe, but it seems to be recognised that these are only of local value. Professor T. C. Chamberlin and his fellow-workers in the North-Central States have, however, adopted a sequence based on the successive advance of different ice-lobes, which is believed to be of wider application; and Professor Chamberlin has tentatively suggested that some of these divisions may have their counterpart in the European scheme, but is careful to show that the correlation must at present remain entirely hypothetical,³ especially as the proposed American grouping may itself require modification.

It is well established that the American ice-sheets, like their European equivalents, radiated from several distinct centres that attained their maximum influence consecutively, and not simultaneously. Of these the 'Laurentide' and the 'Keewatin' sheets had their radiants over comparatively low ground east and west of Hudson Bay, while the 'Cordilleran' sheet spread outward from the Western Mountains. In his general discussion of the glacial phenomena of North-Western Canada, Mr. J. B. Tyrrell⁴ concludes that the Cordilleran sheet had reached its greatest extent and had retired before the boulder-clay of the Keewatin sheet was laid down; and that the Keewatin sheet, in turn, had gone south to its farthest limit, and had retired for many hundreds of miles—more than half-way to its gathering ground—before the Laurentide sheet had reached its greatest extension.

If these conclusions be accepted, they must imply that at least in some cases

¹ 'Die Alpen im Eiszeitalter.' Leipzig (1901-5), not yet complete; for convenient summary see 'Glazialexkursion in die Ostalpen.' No. 12 of *Guides to Excursions of the Geological Congress*, Vienna, 1903.

² e.g., 'The Diversity of the Glacial Period in Long Island,' by A. C. Veatch, *Journ. Geol.*, vol. xi. (1903), pp. 762-776.

³ 'Classification of American Glacial Deposits.' *Journ. Geol.*, vol. iii. (1895), pp. 270-277, and in J. Geikie's *Great Ice Age*, 3rd ed., chap. xli. See also Chamberlin and Salisbury's recent text-book, *Geology: Earth History*, vol. iii. chap. xix (London, 1906).

⁴ 'The Glaciation of North-Central Canada.' *Journ. Geol.*, vol. vi. (1898), pp. 147-161; and 'The Genesis of Lake Agassiz,' *ibid.*, vol. iv. (1896), pp. 811-815.

the recession of the ice-lobes was due to causes acting locally, and not to mild interglacial periods affecting the whole hemisphere. The phenomena of invasion by successive ice-lobes in the peripheral regions might thus be readily explained without recourse to the Interglacial hypothesis.

Most of the detailed evidence brought forward in America to support the Interglacial idea is as fragmentary and unconvincing as that of our own country. But there is one notable exception, to which I must particularly refer, as it has been investigated by a Research Committee of the Association, and has, moreover, come under my personal observation. In this case the interglacial deposits, first described by Dr. G. J. Hinde, are magnificently exposed in cliff sections at Scarboro' Heights, on the shores of Lake Ontario, near Toronto. When I visited these sections under the guidance of my friend Prof. A. P. Coleman, in 1897, they impressed me strongly, inasmuch as they afforded the kind of evidence for which one had sought in vain in Britain. The section around Scarboro' Heights reveals a great mass of fossiliferous stratified deposits, over 180 feet thick, consisting in the lower part of slightly peaty clays, and in the upper part of sands; and these deposits are overlain by a complex series of boulder-clays, with intercalated beds of sand and gravel, attaining a thickness of at least 200 feet. The fossiliferous clays are the lowest beds seen in the cliff section, but beds belonging to the same series, that are exposed in the Don Valley, on the outskirts of Toronto, are underlain by a few feet of boulder-clay, so that it seems to be beyond question that the Scarboro' beds were deposited in an interval between two epochs of glaciation.¹ In their upper part these beds contain a flora and fauna indicating a cool climate, but in their lower portion some of the plants and freshwater shells no longer exist so far north as Canada, and are therefore considered to denote a climate warmer than that of the present day. On this and other evidence it is clear that during the course of the Glacial Period the whole of the district was for a considerable time released from the ice-sheets which previously and afterwards covered it. Moreover, in the opinion of Prof. Coleman, some of the plants and shells of the warm-climate beds denote conditions that would be incompatible with the persistence of ice-sheets anywhere in Canada²; and if this be so, then we here have proof for at least one interglacial epoch. But I still permit myself to feel doubt regarding this last-mentioned deduction, as the shells and plants in question, which have their present habitat in the Middle United States, even yet endure winters of considerable severity; and there are certain factors in the composition of the beds and their altitude above Lake Ontario that justify caution. It is, however, mainly from my knowledge of this 'Toronto formation,' and of the Kirmington section in England, presently to be discussed, that I still maintain an undecided attitude in respect to the Interglacial hypothesis in its simpler form.

Further support to the probability of an interglacial epoch has been adduced from the history of the great lakes which formerly existed in the Interior Basin of the Western States. It has been shown by the researches of G. K. Gilbert in the 'Lake Bonneville' basin³ and of I. C. Russell in that of 'Lake Lahontan,'⁴ that there were two separate epochs, during which these enormous basins were filled with water, and an intervening arid epoch, during which they were dried up. The region is one in which the actual glacial phenomena are restricted to the mountain valleys; but as it seems evident that the lakes were associated in some way with the Glacial Period, the two stages of extension are supposed to represent two distinct epochs of glaciation, separated by a long interglacial drought. The correlation, however, has difficulties, which are very impartially discussed by Gilbert and Russell; and it will not admit of more than one interglacial episode.

¹ Prof. A. P. Coleman, Repts. British Assoc. for 1898, pp. 522-29; for 1899, pp. 411-414; for 1900, pp. 328-340; also (summary and discussion) 'Glacial and Interglacial Beds near Toronto.' *Journ. Geol.* vol. ix. (1901), pp. 285-310.

² 'The Duration of the Toronto Interglacial Period.' *American Geologist*, vol. xxix. (1902), p. 79.

³ 'Lake Bonneville.' *Monogr. U.S. Geol. Survey*, vol. i. (1890).

⁴ 'Lake Lahontan.' *Ibid.*, vol. xi. (1885).

The Interglacial Problem in the British Islands.

Let us now consider the application of the Interglacial hypothesis to our own land.

The task of following up the evolution of Prof. Geikie's scheme through its various phases, though instructive, is very confusing—one might even say irritating—by reason of the continual changes of correlation which its author has suggested in sorting out the British drift deposits into this orderly sequence. Our East Coast boulder-clays, for example, were at one time held to cover four glacial epochs, and their associated gravels to mark three mild interglacial epochs; and all except the first glaciation were supposed to be represented in the boulder-clays of Lancashire and Cheshire.¹ Then, somewhat vaguely, it was allowed that perhaps there were only three separate glaciations on the east coast, with a minor episode of recession of the ice-margin; and the Lancashire and Cheshire boulder-clays were correlated with the two later of these glacial epochs.² But subsequently we are reduced in the eastern district to two epochs of glaciation, with one mild interval, of which the equivalents are all recognised also in the north-west of England.³

While these and other similar changes may show a laudable desire of their author to keep pace with the growth of definite information, I cannot help feeling that they also show the premature character of the whole scheme, and a flexibility in it that justifies suspicion. Moreover, in spite of these frequent changes in the correlation and this local lopping off of glacial and interglacial episodes, we find, with surprise, that the number of separate epochs in the classification has not diminished, but has actually increased, by regrowth in fresh places. This, again, may betoken the inherent vitality of the scheme, in which case it will gain strength from every readjustment; but it must certainly also denote the weakness of its original basis. In considering its application to this country we will begin by glancing at the evidence for the two earliest epochs of the classification.

'Scanian' (First Glacial) and 'Norfolkian' (First Interglacial) Epochs.

It is acknowledged that the First Glacial Epoch is not represented in Britain by any boulder-clay or other evidence of land glaciation, but is based mainly upon the supposed existence of a great Baltic glacier which overflowed the southern part of the Scandinavian peninsula from south-east to north-west, a direction differing widely from that of the later ice-sheets. This glaciation of Scania is supposed to have been contemporaneous with the deposition of the Chillesford Clay and Weybourn Crag of Norfolk, which contain a marine fauna indicative of cold conditions. The Forest Bed series of Norfolk, with its temperate land fauna and flora, is then interpreted as the product of a mild interglacial epoch ('Norfolkian') intercalated between the 'Scanian' glaciation and the more severe 'Saxonian' glaciation which followed; and it is implied that during this mild stage the earlier ice-sheet vanished.

So far as I can gather, the recognition of the 'Scanian' ice-sheet rests on dubious grounds, being based chiefly on the disputed supposition that the lower boulder-clay of North Germany is not the equivalent of the lower boulder-clay of Sweden, but of a subsequent Swedish boulder-clay. For the 'Norfolkian' disappearance of the first Swedish ice-sheet no direct evidence is forthcoming, since it is acknowledged that no interglacial deposits representing this stage have been found in Sweden. But the Norfolk Forest Bed is here brought into the argument to prove the 'deglaciation'—so that the Scandinavian geologist is invited to accept the 'First Interglacial Epoch' mainly on the supposed strength of the British evidence, while the British geologist is expected to acknowledge the 'First Glacial Epoch' on the supposed strength of the Swedish evidence. This method of argument might have weight if the evidence afforded by either region were perfectly definite. But in the present instance the conclusion that the Forest Bed repre-

¹ *Great Ice Age*, 2nd ed. (1877), p. 393. ² *Prehistoric Europe* (1881), pp. 263-266.

³ *Great Ice Age*, 3rd ed. (1894), chaps. xxv. and xxvi., and *Journ. Geol.* (*supra cit.*)

sents an interglacial episode is not acceptable to the observers who have the fullest knowledge of the Norfolk sections, Mr. Clement Reid pointing out that the enclosing of the North Sea by the union of Britain with the southward continental land affords an adequate explanation of the apparent climatal discrepancy between the fauna of the sea and that of land¹; while Mr. F. W. Harmer shows the probability of the transport of southern relics into this old estuarine deposit by river-drifting.²

It has, indeed, been long recognised that the marine Pliocene deposits of eastern England present us with an intelligible chain of evidence for the gradual and uninterrupted approach of the Glacial Period; and to break this chain will require stronger reasons than have yet been adduced. From the Coralline Crag, with seas warmer than at present, to the Red Crag and Norwich Crag, with a northern element steadily gaining ground in the fauna, we pass upward to the Chillesford Clay and Weybourn Crag, wherein this element becomes predominant. Then follows the period of slight elevation indicated by the Forest Bed, wherein, along with its temperate-climate fauna, such northern forms as the musk ox and glutton are associated; and finally we gain just a glimpse of truly arctic conditions in the *Leda myalis* bed and the Arctic freshwater bed, immediately before the advent of the great ice-sheet that relentlessly blotted out both land and sea.

‘*Saxonian*’ (Second Glacial), ‘*Helvetian*’ (Second Interglacial), and ‘*Polandian*’
(Third Glacial) Epochs.

Regarding the glacial severity of the ensuing stage—the ‘*Saxonian Epoch*’ of Professor Geikie’s scheme—all are agreed; and from this stage onward to the close of the ‘*Glacial Period*’ as usually understood, or to the close of the ‘*Polandian Epoch*’ of the proposed classification, our difficulties of interpretation arise not from lack of evidence, but rather from its superabundance and local intricacies.

It happens, fortunately, that the great bulk of our British drifts, with the exception only of those in certain mountainous districts, are now included by Professor Geikie within the two above-mentioned glacial epochs and the intervening ‘*Helvetian Interglacial Epoch*.’ Therefore, in dealing more particularly with the deposits assigned to these three epochs in certain typically glaciated districts, we shall bring under consideration a considerable portion of the drifts of our islands, and shall obtain results which can be applied to many other areas in which the structure of the glacial deposits is essentially similar. The first district to be considered shall be that which lies nearest us; and in discussing the drifts of East Yorkshire I propose to interweave some personal opinions that I have deduced from the facts, which will afterwards be given wider application.

EAST YORKSHIRE DRIFTS.—The long cliff-sections between the Humber and the Tees constitute one of the best exposures of lowland drifts in Britain, or even in Europe. They fortunately include some deposits which reveal the conditions prevailing in the neighbouring part of the North Sea basin just before the great glaciation; and they therefore enable us without interruption to continue the history begun in East Anglia.

The old cliff of chalk and the marine beach at its foot which lie buried at Sewerby, on the southern side of Flamborough Head, under sheets of boulder-clay and gravel, prove to us that at the very beginning of glacial times the North Sea still held possession of its basin, and with a surprisingly slight difference from its present level. A few far-transported stones in the old beach denote that ice-floes sometimes drifted southward into Holderness Bay; while the bones of animals in the shingle, and in the blown sand which overlies it, prove that among the denizens of the neighbouring land were the elephant (*E. antiquus*), rhinoceros (*R. leptorhinus*), hippopotamus (*H. amphibius*), and bison. This fauna is frequently considered to be proof of mild conditions of climate; but from the mode of its occurrence in this and other places, I can find no reason to doubt that these

¹ ‘The Pliocene Deposits of Britain.’ *Mem. Geol. Survey* (1890), pp. 186–190.

² ‘The Later Tertiary History of East Anglia.’ *Proc. Geol. Assoc.*, vol. xvii. (1902), p. 449.

animals inhabited the country, perhaps as seasonal migrants, until the time that it was actually covered by the encroaching ice-sheets.

And here I may note my opinion, that throughout the discussion of our glacial deposits too much weight has been allowed to the deductions regarding climate based upon scanty indications afforded by the ancient fauna and flora. We know little regarding the range of adaptability possessed by the forms in the past, and can judge only from their present habitat, which is generally governed by many other factors besides climate; moreover, it is granted that species already established, when subjected to gradual change, will persist for long under circumstances that would have effectively barred their introduction. In the Upper Zambesi Valley last year I was more impressed with the cold of the nights than with the heat of the days; and even at that latitude the sturdy hippopotamus in his nocturnal raids must experience a temperature occasionally descending below freezing-point.

It took us long to break away from the established conviction that the fossil elephant and rhinoceros could not have existed in a cold climate; and the same conviction still lingers with respect to their companion, the hippopotamus. But the far-travelled stones in the Sewerby beach and in the beaches of the same age in the south of Ireland are evidence that the British seas were already cold enough to carry ice-floes while these large mammals still tenanted the land.

The next event indicated by the Sewerby section is a slight elevation of the land. Then the traces of an increasingly rigorous climate become conspicuous, for the sand-dunes which had been banked against the old cliff are covered by chalky rubble containing a few land shells¹; and this material, like the corresponding 'head' which covers the ancient beaches of the south of Ireland and the south-west of England, appears to represent the frost-splintered rock washed down from the rock slopes during the season of thaw.

According to my reading of the evidence, it was during this time that the bed of the North Sea was gradually filled by a great ice-lobe that spread southward and outward along the basin, slowly but irresistibly churning up and dragging forward the old sea-floor as part of its ground-moraine. When it impinged upon the rising ground of eastern Britain the progress of this sheet was arrested and part of its burden left in the form of the lowest boulder-clay—the 'Basement Clay' of Yorkshire and the 'Cromer Till' of Norfolk. In Yorkshire this boulder-clay frequently includes huge transported masses of Secondary strata, which still maintain their identity, in some cases even to their bedding planes; and along with these we sometimes find patches of the material of the old sea-floor which have similarly escaped destruction. More frequently the pre-existing deposits from which the boulder-clay has been derived have been thoroughly kneaded together, and fragments of Pleistocene shells are then scattered through its mass, along with fossils derived from the Secondary and older rocks.

In adopting the hypothesis that the Basement boulder-clay represents the ground-moraine of an ice-sheet we may consider briefly the probable conditions under which this 'East British ice-lobe' was accumulated. Whether the elevation subsequent to the stage represented by the infra-glacial beaches was sufficient to drain off the shallow seas around our islands is uncertain, but it must, at any rate, have restricted their area and rendered them still shallower; and it is unlikely that there was then any southward connection of the North Sea with the English Channel. The climate by this time had become such that permanent snow-caps could accumulate in the northern parts of our country at elevations not much above present sea-level. Indeed, I am inclined to think that the climate may have been actually colder at this time than during any of the later phases of the Glacial Period, and that the stage of maximum glaciation lagged considerably behind the stage of minimum temperature. Under these conditions, with the snowfall on the uplands always slowly drawing away in ice-streams to the basins, and there accumulating, it is inevitable that the enclosed basins would eventually become ice-covered, any open water within them being in time obliterated,

¹ Lamplugh, *Proc. Yorks. Geol. Soc.*, vol. xv. (1903), pp. 91-95.

either directly by the encroaching glaciers, or indirectly by the packing of bergs and floes, until the basins themselves possessed a surface upon which the snow-fall could accumulate. Thus the basins became great reservoirs of ice, in which the supplies from the surrounding uplands received important augmentation by direct accretion of snowfall;—reservoirs, moreover, containing a substance sufficiently rigid not to require retaining walls; so that, in time, the surface of the ice within the basins rose higher than many parts of the rim. The general movement of the mass within its reservoir then became dependent mainly upon its own configuration, and only secondarily upon the shape of the solid ground.

These conditions in the North Sea basin had their parallel in the basin of the Irish Sea, in which the 'West British ice-lobe' was developed; and on the low interior plain of Ireland, where the similar though smaller 'Ivernian' sheet held possession.

Now, the crux of the Interglacial problem, so far as the British Islands are concerned, lies in the question whether these huge reservoirs, after their first filling, were completely emptied during the supposed interglacial epoch of warmth named by Professor Geikie the 'Helvetian,' and were afterwards refilled for the later 'Polandian' glaciation, in which, on the evidence of the upper boulder-clays, it is generally agreed that ice-sheets from the basins again closed in upon the land. It is this one interglacial or 'middle glacial' epoch only that most of the British supporters of the hypothesis have demanded, and have attempted to establish in the East Yorkshire sections.

For my own part, although I have sought long and carefully for evidence of this great interglacial episode in the Yorkshire drifts, and at first with the belief that such evidence must surely be somewhere forthcoming, my search has not only failed to bring to light any adequate proof of its reality, but has yielded many facts which I cannot explain otherwise than by recognising that the ice-lobe continued to occupy the basin of the North Sea during the deposition of the beds claimed as interglacial, though its margin had for a time shrunk considerably within its earlier limits.

The 'Purple' Boulder-Clays and Stratified Drifts.—The drifts overlying the Basement Clay in East Yorkshire consist of a complex and very variable series, in which bands of boulder-clay predominate in some places and lenticular sheets of well-stratified material in others. In the cliff-sections of the Holderness plain certain bands of boulder-clay, known as the Upper and Lower Purple Clays, are persistent for many miles; but when the series approaches the rising ground of the Wolds the individuality of the beds is lost, and they are often replaced entirely by irregular mounds of sand and gravel.

I began work on these sections with the then-prevalent idea that every separate band of boulder-clay above the Basement Clay might indicate a separate glacial epoch, and that warm interglacial epochs might be represented by the partings of sand and gravel between these boulder-clays; and the object of one of my early papers¹ was to show that more of these divisions were present than had found place in the scheme of classification then in vogue. But after struggling for a time under an ever-increasing load of epochs I was compelled, in tracing the separate bands northwards, to recognise, as my friend Mr. J. R. Dakyns had previously recognised,² that the whole series underwent protean changes, the boulder-clays sometimes splitting into numerous shreds amid thick sheets of sand and gravel, at other times merging into a single mass to the exclusion of all stratified material, and not rarely presenting a passage from uncompromising 'till' to stratified gravel, sand, and clay. Hence I was driven to conclude that stratified and unstratified drift must often have been forming simultaneously at places very little distance apart; and on finding, also, that the whole of the deposits between the Basement Clay and the Upper or 'Hessle' Clay were not only knit together in this fashion, but were similarly interwoven with the top and bottom of these boulder-clays, I had finally to abandon the Interglacial hypothesis altogether so far as the

¹ 'On the Divisions of the Glacial Beds in Filey Bay.' *Proc. Yorks. Geol. Soc.*, vol. vii. (1879), pp. 167–177.

² 'Glacial Beds at Bridlington.' *Ibid.*, vol. vii. (1879), pp. 123–128.

coast-sections were concerned. I mention this experience in order to show that my present scepticism respecting the Helvetian Interglacial Epoch is based, not upon any preconceived objection to the idea, but upon the failure of the hypothesis when I have put it to the test in this and other districts; and I find also that my experience in this particular runs parallel with that of many other investigators of the so-called 'middle glacial' deposits of England.

Marine Detritus in Glacial Gravels.—From certain characters of the moundy gravels on Flamborough Head and in Holderness, such as their rudely linear arrangement, their indifference to the contours, and their relation to the middle or Purple boulder-clays, it appears most probable that they represent the material deposited along the margin of the ice-sheet by the surface-waters flowing from it and from the adjacent land.¹ From the occurrence of more or less fragmentary marine shells in them, the gravels were, however, originally supposed to be of marine origin, and this view is still upheld by some geologists. It is the same question in which so many of the so-called 'middle glacial' sands and gravels of the British Islands are involved, and upon which there has been so much discussion. If it be permissible for me to reiterate the well-known argument by which the presence of marine shells in gravels of glacial origin is explained, it may be outlined as follows.

Since the basins around our islands are known to have been occupied by the sea at the beginning of the Glacial Period, and since these basins were afterwards filled by ice-lobes, which, as we have seen, moved outward in many places upon the land, dragging with them much of the material of the old sea-floor, it is inevitable that a certain amount of marine detritus will occur in the deposits formed by the ice or derived from its melting. Just as we find shells, and sometimes even transported masses of marine deposits, intact in the Basement Clay, so we find marine relics likewise, though usually more scattered and less perfect, in the gravels derived from the same ice-sheet. This deduction is consistent with our knowledge of existing glaciers and ice-sheets; thus, Sir Archibald Geikie has recorded the presence of sea-shells in the moraine of a Norwegian glacier²; Professors E. J. Garwood and J. W. Gregory have found an excellent illustration of the same phenomenon in one of the Spitzbergen glaciers³; and Professor R. D. Salisbury, in describing the characteristic upturning of the layers of ice at the end of one of the glacial lobes which descends into a shallow bay in North Greenland, gives the following instructive note on the conditions which he observed: 'Here the upturning of the layers brought up shells from the bottom of the bay, and left them in marginal belts where the upturned layers outcropped. These shells were mingled with other sorts of débris. In one case their quantity could have been measured by some such unit as the wagon-load.'⁴

In our islands, as Professor P. F. Kendall has clearly shown in discussing the drifts of Western England,⁵ it is only where the ice-lobes have passed over portions of the pre-existing sea-floors that we find marine remains in the drift deposits; while in other places, at the same or lower elevations, where there is proof that the ice-flow was from the land, such remains are invariably absent.

The occurrence of these shells in a few places at high elevations, all explicable by consideration of the geographical circumstances, gave rise to the idea of a great mid-glacial submergence, and upon this idea the hypothesis of a mild interglacial epoch has mainly hinged. In Professor Geikie's latest scheme this supposed submergence is, indeed, reduced to moderate limits, but it is still the essential factor in the argument.

¹ Lamplugh, 'Drifts of Flamborough Head.' *Quart. Journ. Geol. Soc.*, vol. xlvii. (1891), pp. 384-431.

² *Geological Sketches at Home and Abroad* (London, 1882), pp. 145-146.

³ 'Contributions to the Glacial Geology of Spitzbergen.' *Quart. Journ. Geol. Soc.*, vol. liv. (1898), p. 210.

⁴ 'Glacial Geology of New Jersey.' *Rep. Geol. Survey of New Jersey*, vol. v. (1902), p. 81. (The quoted italics are in the original.)

⁵ In the late Professor H. Carvill Lewis's *Glacial Geology of Great Britain and Ireland* (London, 1894), Appendix A, pp. 425-431.

The same idea of a moderate degree of submergence, accompanied by temperate conditions of climate has been applied by Mr. Clement Reid¹ to the shelly gravels of Holderness. Mr. Reid has also proposed to include the buried cliff-beds of Sewerby in the same interglacial stage; but as the gravels rise to nearly 100 feet above the level of the old beach in northern Holderness, and are separated from it by the Basement boulder-clay, I am sure that this correlation cannot be sustained.

These Holderness gravels are supposed to be absent from the coast sections, and it is suggested that they may lie below sea-level in this quarter; but this is not very probable, as they are found at an elevation of 50 feet within a few miles of the coast in southern Holderness, and the Basement boulder-clay rises well above sea-level in the cliffs at Dimlington. It is true that the gravels of the coast sections afford no support to the idea of a mild interglacial submergence, and are evidently of similar origin with the rest of the glacial deposits, but I can see no other reason against their correlation with the gravels of the neighbouring interior. Except in two or three limited tracts, the shells in the Holderness gravels are as fragmentary, and nearly as scanty, as in the moundy gravels of Flamborough Head, which from their character and position cannot be of marine origin. Even at the exceptional places referred to, where the fossils are more plentiful, there is a mixture of forms, including an abundance of the freshwater shell *Corbicula fluminalis*, which seems to denote their derivation from pre-existing local deposits; and in the new section at Burstwick, described by Mr. T. Sheppard,² these shelly gravels revealed the same close association with the boulder-clay that is so frequently displayed in the glacial gravels of the coast sections.

The Kirmington Section.—There is, however, one case known to me in the east of England, and only one, in which an undoubtedly contemporaneous fauna occurs in beds intercalated with the boulder-clay series.³ At Kirmington, in North Lincolnshire, a brickyard is worked in a deposit of estuarine clay lying in the middle of a broad shallow valley which cuts across the Chalk Wolds about eight miles south of the Humber. Recent investigation by a Research Committee of the Association, in which I took an active share, has shown, somewhat unexpectedly, that the surface of the chalk at this place descends to present sea-level, and that the estuarine warp is underlain by over 60 feet of drift, consisting of sand and chalky gravel, with two thick bands of tough clay containing far-travelled stones.⁴ The boring in which these beds were proved was insufficient to show precisely whether the stony clays possessed the distinguishing features of true till, but there can be no doubt as to their glacial character, since we know of no deposits of this kind in the east of England except those of glacial age. At the base of the estuarine warp, at 65 feet above Ordnance datum, we found a thin seam of silt and peat containing a few freshwater shells and plant remains, which, like the very scanty fauna of the overlying warp, give no precise indication of climatal conditions, though suggesting that the climate was cooler than at present. The estuarine bed is overlain by a coarse gravel of rolled flints, and in one part of the section this gravel is covered by 3 or 4 feet of red clay with far-travelled stones, resembling the Upper boulder-clay or Hessele Clay of Holderness. The character and fauna of the warp show that it must have been laid down between tide-marks, and we therefore gain an exact measure of the sea-level at the time of its accumulation, and also, I think, of the highest limit of marine submergence in this part of England during any stage of the Glacial Period.

¹ 'The Geology of Holderness.' *Mem. Geol. Survey* (1885).

² 'On another Section in the so-called Interglacial Gravels of Holderness.' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiii. (1895), pp. 1-14.

³ The freshwater deposit which I found some years ago at Bridlington, and at first thought to be probably intercalated with the boulder-clay, proved on fuller exposure to lie above the boulder-clay, with which it had become entangled by later disturbance. See *Geol. Mag.*, dec. ii., vol. vi. (1879), p. 393; and *Proc. Yorks. Geol. and Polytech. Soc.*, vol. vii. (1881), p. 389.

⁴ *Rep. British Assoc.* for 1904, pp. 272-274.

The position of the deposit, at the fringe of the great sheet of drift which covers the lowland east of the Wolds and on the edge of an area west of the Wolds which appears to have escaped glaciation, sustains me in the opinion that it was accumulated during that temporary recession of the East British ice-lobe of which we have other evidence. Its proposed correlation with the Holderness gravels seems hardly tenable in the light of the fuller information which we now possess regarding the section. That the East British ice-lobe, during one of its phases, had the sea at its margin, has always appeared to me to be probable,¹ and, I think, supplies an adequate explanation of the facts.

Under this interpretation the complex drifts between the Basement Clay and the Hessele Clay are regarded as the marginal products of the ice-lobe which filled the North Sea Basin during a stage when its western border began to lose ground by rapid wasting. By this recession a broad hollow was left between the hills and the ice-sheet, and into this hollow were swept the abundant washings from the glacier on the one side and from the bare land on the other, thus forming the irregular mounds and broad fans of stratified material which run parallel with the receding ice-border. The sea at this time encircled the southern end of the ice-lobe, but its waters were restricted, in the area under consideration, to narrow estuarine inlets between the ice and the land.

The Upper Boulder-Clay.—Concurrently with this shrinkage of the East British ice-lobe there appears to have been a steady increase in the ice-caps which covered the broader upland tracks of the northern English counties. But all the evidence tends to show that the tongues descending eastward from these caps, from the time of the Basement Clay onward to the close of the glaciation, were persistently prevented from passing freely outward by the presence of the main lobe in the North Sea Basin. Upon the shrinkage of the main lobe they were deflected southward along the hollow between it and the hilly land, which, in time, they filled again to a somewhat higher level than before, the inoculation of the upper and lower Purple boulder-clays with the stratified drifts marking the gradual stages in this process. The magnificent cliff-sections of the Yorkshire coast north of Flamborough reveal the continuous character of this glaciation, and there is no room anywhere to wedge an interglacial period into these sections. South of Flamborough, the interval between the withdrawal of the one mass and the advance of the other was longer, because the passage of the new invader to the eastward of the Oolitic hills was only gradually effected; and consequently it is in the interior of the Holderness recess that we find the greatest development of the stratified drifts. To imagine, with the interglacialists, that the North Sea Basin was emptied of its ice-sheet, and was then filled again just far enough to influence the flow of the local ice, without extraneous re-invasion of our coast, seems to me an unwarranted sacrifice of the evidence to the idea.

Local Shrinkage in the Ice-sheets.—There are many indications, especially in the Midland Counties and along the southern margin of the glaciated region, that the several lobes and tongues of ice of the Glacial Period in Britain did not all attain their maximum development at the same time, but that while some were creeping forward, others were shrinking back. To a certain extent this result may have been brought about simply by changes in the currents as the ice-sheets overwhelmed their erstwhile confining rims of bare land and opened up fresh avenues of discharge.

It appears to me, however, that the prime factor lay in the displacement of the areas of greatest precipitation during the course of the Glacial Period.² As the plateaus of ice rose higher in the path of the moisture-laden air-currents they must have gained increased effectiveness as condensers, thereby not only augmenting the snowfall in one quarter, but also diminishing the precipitation in the region to leeward. Hence I imagine that there would be a persistent tendency for the great ice-sheets of Western Europe to thicken and spread more rapidly

¹ 'Drifts of Flamborough Head.' *Quart. Journ. Geol. Soc.*, vol. xlvii. (1891), p. 421.

² *Glacialists' Mag.*, vol. i. No. 11 (1894), p. 231; and *Mem. Geol. Surrey*, 'Isle of Man' (1903), p. 395.

toward the west than toward the east, until finally the eastern portions were shrunken for want of sustenance, while the westerly lobes were still waxing thicker and stronger. The recent researches of Mr. F. W. Harmer into the probable meteorological conditions of the Glacial Period¹ are full of suggestion in their bearing upon the changes which must have been brought about by the expansion of the ice-sheets. The subject is one of peculiar difficulty, but I believe that the solution of many of the problems connected with the Glacial Period are to be found along the lines of Mr. Harmer's investigations.

In considering this factor it is also especially interesting to find that Captain R. F. Scott is of opinion that the great shrinkage in the Antarctic land ice, of which he obtained such convincing evidence during the recent expedition, is due to the present excessive coldness, and consequent dryness, of the climate; and he assigns the former extension of the southern ice-sheets to a period of warmer and moister conditions.² It would have been easy, had time permitted, to bring together numerous illustrations from Polar lands to show how strongly localised in many places are the conditions of existing glaciation; and such conditions must have been still more effective at lower latitudes. Hence we can readily imagine that, during the Glacial Period, differential growth and shrinkage might be brought about concurrently in areas not very wide apart, by local circumstances.

Waning Ice-sheets.—So far as the eastern side of England is concerned, I think that the epoch of maximum glaciation was reached, not when the East British lobe pressed farthest westward, but when the Pennine and North British ice advanced southward along its receding flank; and this stage is, I presume, equivalent to the 'Polandian Glacial Epoch' of Professor Geikie's classification. It was at this time that the ice lapped highest around the slopes of the Jurassic and Cretaceous uplands of Yorkshire, causing that radical diversion of the surface-drainage which produced the remarkable effects first made known to us by the brilliant researches of Professor P. F. Kendall in Cleveland,³ and since traced by him and his fellow-workers at intervals wherever the margins of the ice-sheets have abutted against the slope of the land.

Farther southward this ice, augmented by the snowfall on its own broad surface, appears to have spread over the lower ground far beyond the bounds of the former invasion, covering most of East Anglia and the East Midland counties with a moving ice-cap, beneath which the Chalky boulder-clay was accumulated. The Upper boulder-clay of Yorkshire I consider to be the product of the same ice-sheet at its waning.

This final waning of the British ice-sheets, as I have elsewhere attempted to show,⁴ must have been accompanied by conditions very different from the waxing stages. It appears from the evidence that the great ice-plateaus still lingered in their basins even after the amelioration of the climate had progressed so far that no permanent snow could remain on hills that rose considerably above their level. Deprived of reinforcement, and wasting ever more rapidly as their surfaces were brought lower, the lobes must in all their embayments have passed into that condition of 'dead ice' with which the explorers of Polar regions have made us familiar. The 'englacial' load of detritus which the ice was powerless farther to transport was gradually dropped to the ground, and often modified and spread by gravitational movement in the saturated mass.⁵ The peculiar features of the upper part of the lowland drifts were thus explained many years ago by the late J. G.

¹ 'The Influence of Winds upon Climate during the Pleistocene Epoch.' *Quart. Journ. Geol. Soc.*, vol. lvii. (1901), pp. 405-476.

² 'Results of the National Antarctic Expedition.' *Geograph. Journ.*, vol. xxv. (1905), p. 306.

³ 'A System of Glacier-Lakes in the Cleveland Hills.' *Quart. Journ. Geol. Soc.*, vol. lviii. (1902), pp. 471-571.

⁴ 'The Geology of the Isle of Man.' *Mem. Geol. Survey* (1903), pp. 395-397.

⁵ The flow of loose material at the surface when saturated by water has been recently studied by J. G. Andersson (Upsala), who cites many remarkable illustrations of the phenomenon, and proposes to apply to it the term 'solifluction.' *Journ. Geol.*, vol. xiv. (1906), pp. 91-112.

Goodchild, in his luminous description of the glacial deposits in the Vale of Eden,¹ and his conclusions have been supported by the researches of Dr. N. O. Holst in Southern Greenland, where there was found to be the same difference between the unoxidised ground-moraine and the overlying oxidised material of 'englacial' origin as between the lower and upper boulder-clays in areas of ancient glaciation.² In adopting this explanation we must recognise that the uppermost boulder-clay of an extensive area was not formed at exactly the same time in every part, but was accumulated progressively as a marginal residue during the emergence of the land from its icy cloak.

Late Glacial and Post-Glacial Deposits.—Of the glacial and interglacial epochs of Professor Geikie's scheme later than the 'Polandian' it is admitted that no indication has been found in Yorkshire. There seems, on the contrary, to be evidence of steady amelioration in the climate, as the glacial deposits opposite the mouths of the Wold valleys are overlain, first by great deltas of chalky gravel, denoting torrential floods, probably from the seasonal melting of heavy snows; and then, in the hollows of these gravels, or of the boulder-clay itself, we find freshwater marl and peat that were deposited in the many lakelets and marshes that dotted the Holderness plain; and in the lower layers of certain of these freshwater deposits the leaves of the arctic birch (*Betula nana*) have been detected,³ indicating a climate colder than at present.

In East Yorkshire, then, we appear to have a continuous record of the events from the beginning to the end of the Glacial Period; and yet, if I read the sections aright, we can find no place into which a single mild interglacial epoch can be intercalated.

Let us now more briefly consider certain glaciated areas within the influence of the 'West British' ice-lobe which I have personally investigated.

DRIFTS OF THE ISLE OF MAN.—From its isolated position in the midst of the Irish Sea, the Isle of Man constitutes an excellent gauge or glaciometer, on which is recorded the course of events within the basin occupied by the West British ice-lobe. In carrying out the geological survey of this island I made a close examination of its glacial deposits in every part, and have stated the results rather fully in a recently published memoir.⁴

We find here, as in Yorkshire, that prior to the glaciation there was a sea-margin at approximately its present level and, where the coast is composed of 'solid' rocks, in approximately its present position. In this sea, marine deposits indicative of cold conditions were accumulated, and were afterwards displaced and mingled with the boulder-clay of an ice-sheet that gradually filled the basin and swept southward, or south-south-eastward, over the very summit of the island. At its maximum the surface of this ice-sheet stood more than 2,000 feet higher than present sea-level. The difference between the altitude attained by this ice and that of the East British lobe in the same latitude is especially noteworthy. In Yorkshire the eastern ice did not reach much above 800 feet on the flanks of the Cleveland Hills, declining to 500 feet or under off Flamborough Head. The higher land which surrounds the Irish Sea Basin may be in part responsible for this difference, but I think that it must have been mainly due to the heavier precipitation in the west.

Then followed a declining stage in the glaciation, during which the ice-sheet

¹ 'Ice Work in Edenside.' *Trans. Cumberland Assoc.*, No. 12 (1886-7), pp. 111-167.

² 'Dr. N. O. Holst's Studies in Glacial Geology,' by Dr. J. Lindahl, *American Naturalist*, Aug. 1888, pp. 705-712. It should be noted, however, that Professor R. D. Salisbury did not find this difference apparent in the moraines of North Greenland glaciers. See *Journ. Geol.*, vol. iv. (1896), pp. 806-807.

³ By Dr. A. G. Nathorst, at Bridlington; and by C. Reid, at Holmpton. *Geology of Holderness*, pp. 78 and 85.

⁴ 'The Geology of the Isle of Man' (1903). *Mem. Geol. Survey*.

shrank away from the hills, which were never again covered. Owing to local circumstances that are readily recognisable, the recession of its margin was relatively accelerated in the northern part of the island, so that a broad hollow was formed there between the hills and the ice-border; and in this hollow a mass of stratified drift was deposited. From its terraced aspect and the occurrence of scattered shells, I thought at first that this deposit might be of marine origin; but examination in detail convinced me, as it had previously convinced Prof. P. F. Kendall,¹ that the phenomena could only be explained by regarding the stratified material as marginal 'overwash' from the ice-front. As in Yorkshire, the association of the boulder-clays with the stratified drift is in most places so intimate that again the evidence for the continuous presence of the ice-sheet in the surrounding basin seems irrefragable.

Following closely upon this local deposition of stratified drift, there appears to have been a limited readvance of the ice, which brought about the accumulation of an upper boulder-clay on parts of the low ground. But, unlike the Upper Clay of Yorkshire, this bed lies well within the limits of the lower clays, both in extent and elevation; and it seems to denote only a slight augmentation of the persisting ice-sheet, which was thus enabled to close in again upon the lower flanks of the hills.

The end of the glacial invasion was marked by similar conditions to those found in Holderness. Great fans of flood-gravel were spread out around the mouths of the upland glens; and the hollows in the drift-plain were occupied by lakelets, now mostly obliterated by an infilling of marly and peaty sediments. Among the plants found in a bed near the base of one of these hollows is a northern willow (*Salix herbacea*), along with the remains of a minute arctic freshwater crustacean (*Lepidurus glacialis*); and similar remains were also found in a peaty layer interbedded with the flood-gravels.

Here, then, is another area in which the drifts are fully developed and magnificently exposed in cliff sections, but still yield no proof of the supposed interglacial epochs or of the marine submergence.

IRISH DRIFTS.—During recent years, while attached to the staff of the Geological Survey in Ireland, I had occasion systematically to examine the drifts of four separate and typical areas. With my colleagues of the Irish staff, the mapping of the superficial deposits was carried out in the country around the cities of Dublin, Belfast, Cork, and Limerick. The results, which have been fully stated in recent publications of the Survey,² differ only in detail from those already dealt with, and need not detain us long.

Cork District.—In the south of Ireland, the infra-glacial beach, with its associated cliff and shore-line, discovered by Messrs. H. B. Muff and W. B. Wright,³ is essentially similar to the buried cliff at Sewerby and at almost exactly the same level. The presence of the old beach-line within the submerged valleys or *rias* of this coast proves that the valleys were excavated during some earlier stage of elevation. In its eastward extension the beach, with its covering of sub-aërial land-waste or 'head,' is overlain by the shelly boulder-clay of the West British ice-lobe; but in the south-west of Ireland, where the glaciation was from landward, this boulder-clay is absent, and its place is taken by a till of more local origin. The Cork district appears to have lain not far within the southerly bounds of the ice-sheets, and its valleys were filled to the brim almost entirely with ice from the interior of Ireland. Where the products of this ice are seen in contact with the shelly drift, as in the vicinity of Youghal, the latter lies

¹ 'On the Glacial Geology of the Isle of Man.' *In Lioar Manninagh*, vol. i. pt. 12, pp. 397-438.

² *Mems. Geol. Survey*: 'The Geology of the Country around Dublin' (1903); 'The Geology of the Country around Belfast' (1904); 'The Geology of the Country around Cork and Cork Harbour' (1905); 'The Geology of the Country around Limerick' (in press).

³ Wright and Muff, 'The Pre-glacial Raised Beach of the South Coast of Ireland.' *Sc. Proc. Roy. Dublin Soc.*, N.S., vol. x. pt. 11 (1904), pp. 250-324.

undermost; but the evidence implies that the two ice-sheets were coexistent, and there is no indication of any break in the glaciation.¹ Both here and in the Dublin district there appears to have been a shrinkage in the West British lobe while the Ivernian ice was still advancing, which again points to a shifting westward of the area of greatest precipitation.

Owing to its peripheral position, the Cork district seems to have been set free from its ice-mantle much earlier than the more northerly parts of Ireland; and if there had been marine submergence later than the period of maximum glaciation, it should have left clear traces in this area. But we found, instead, that all the deposits newer than the boulder-clay were unmistakably of fluvial or sub-aërial origin, and occupied positions that they could not have maintained if any submergence had occurred.

Dublin District.—In the Dublin district the lower shelly boulder-clay was carried for some distance inland during an early stage in the glaciation, but afterwards there was a great outpouring of the Ivernian ice from west-north-west round the northern flank of the Dublin Mountains. As the Pennine ice was deflected southward on reaching the North Sea Basin, so was this Ivernian ice deflected southward parallel to the coast in the Irish Sea Basin, the persistence of ice-lobes within the basins being the only adequate explanation in both cases.

The shelly gravels associated with the Dublin drifts are of peculiar interest, since they occur at heights ranging up to 1,200 feet above sea-level, and are typical of the other high-level shelly drifts of the 'West British' basin, including the much-discussed deposits of Moel Tryfaen and Macclesfield. The position of these gravels on the flanks of the Dublin Mountains at the margin of the heavily drift-covered country, their moundy outlines, sporadic development, disregard for contours, character of the fauna, relationship to the boulder-clay, and, in fact, every feature they possess, tell against the possibility of these gravels being of marine origin or other than the marginal deposits of the ice-sheet. Gravels at much lower levels in the same district that are associated with the ice-flow from the interior of the country contain no shell fragments.

The fine coast sections between Killiney and Bray show the usual features of a lower shelly boulder-clay brought in obliquely from the seaward and an upper boulder-clay derived from the landward ice; and they show, too, that the so-called 'middle glacial' gravels are merely local modifications of the glacial series, interwoven with the boulder-clays and of contemporaneous accumulation. In this district there is again strong evidence that the land remained above sea-level during the final waning of the ice, and that it has not since undergone any submergence, except to a depth of not more than 10 feet above present sea-level.

Belfast District.—In the country around Belfast the glacial phenomena presented the same general features. The principal constituents were again—a shelly boulder-clay, brought in from the northward, interlocked in a few places with moundy gravels, also containing a few shell fragments; and a contemporaneous drift in the hilly interior of more immediately local origin, associated with gravels of like composition and without any marine relics.

The only new feature was the presence of a mass of unfossiliferous sand and laminated clay in the recess at the head of Belfast Lough, which appears to have been deposited in a glacially dammed lake during the waning phase of the glaciation. This deposit is in places interbedded with and partly overlain by boulder-clay. Its relation to the surrounding drifts seems only explicable under the supposition that the oscillating margin of the ice-lobe was continuously present in the vicinity; and nowhere in the district did we find any evidence to suggest that there were epochs of glaciation separated by warm interglacial episodes.

The conditions in this district subsequent to the disappearance of the ice-sheets are recorded in the post-glacial deposits at the head of Belfast Lough, which have been carefully investigated by Mr. R. Lloyd Praeger.² A bed of peat,

¹ Wright and Muff, *op. cit.*, p. 272.

² 'Report on the Estuarine Clays of the North-east of Ireland.' *Proc. Roy. Irish Acad.* (3) vol. ii. (1892), pp. 212-289.

passing considerably below sea-level, proves that at first the land stood higher than at present, while the estuarine clays which overlie this peat demonstrate a more recent submergence to a depth of not more than 15 or 20 feet above present sea-level. This degree of submergence is marked also by the raised beach which almost everywhere fringes the north-eastern coast of Ireland, and there is no adequate evidence for any other epoch of submergence in Ireland between the beginning of the Glacial Period and the present time.

Limerick District.—In the country around Limerick we had to deal with the products of the Ivernian ice-sheet only, uncomplicated by exterior invasion; and here not even the staunchest supporter of Interglacial deglaciation and submergence could have found a basis for his hypothesis. Although the drifts occur thickly on low ground falling to sea-level, as well as on the hills, and although they include numerous eskers and broad fans of sand and gravel, not a single shell fragment has been discovered in them, nor any other indication of marine agency. On the other hand, there is abundant evidence that the boulder-clay and the stratified drift were formed contemporaneously, the one by the ice-sheet itself, and the other by the flood-waters in and around it. Another noteworthy point in this district is that, in spite of its proximity to the west coast, with the broad estuary of the Shannon offering at present an open passage thereto, the general movement of the land-ice was south-eastward across the low ground, trending inland, and not toward the coast. It appears, therefore, that the ice-sheet at the mouth of the Shannon was sufficiently thick to dominate that of the country to the east in this part of Ireland. Farther to the northward, however, and also to the southward, it is known that ice-lobes passed outward toward the Atlantic.

I think that this review of the testimony from the areas which I have closely investigated will serve to show how extraordinarily elusive is the evidence for even the principal Interglacial epoch of the proposed scheme. I shall venture to claim that in each of these areas all the available data concerning the superficial deposits were systematically examined in the field and conscientiously sifted, without prejudice towards one opinion or another. Yet the only support which has been found for the Interglacial hypothesis is from a single section in North Lincolnshire, and although in this case the facts give some encouragement to the idea, they can be as readily explained without recourse to it.

In view of some evidence which we have still to consider, it is especially remarkable that in the range of magnificent coast sections, not of these areas alone but of the whole of our islands, there is not, so far as I am aware, a single known occurrence of fossiliferous land deposits, peaty or otherwise, interbedded with boulder-clays; and we have, therefore, to depend entirely upon much less satisfactory exposures in the interior of the country for evidence of this kind.¹

After the experience above recorded, it is inevitable that I shall approach the remainder of the British evidence for the Interglacial hypothesis in sceptical mood, though, I hope, without dogmatism. In discussing this evidence from districts of which my personal knowledge is scanty, or altogether wanting, I shall perforce have to depend mainly upon the literature of the subject, although I am fully aware that, of the opinionative churning of this literature there has already been more than enough.

East Anglia.—In East Anglia, the original opinion that the shelly 'middle glacial' sands and gravels represent a mild interglacial epoch of submergence is no longer prevalent. Mr. F. W. Harmer² points out that both the mollusca and

¹ I did, indeed, at one time think that I had discovered an ancient soil with land shells between two boulder-clays in the cliffs of Filey Bay, but after much examination I found that it was a recent soil, covered by a huge slip of boulder-clay from the upper part of the cliff and then exposed in section by the cutting back of the coast.

² 'The Later Tertiary History of East Anglia,' *Proc. Geol. Assoc.*, vol. xvii. (1902), pp. 458-462; and 'Pleistocene Deposits of East Anglia,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xv. (1904), p. 322.

ostracoda they contain are generally of a boreal or arctic character; and my colleague, Mr. H. B. Woodward, after extensive field-experience of these deposits, concludes that they are inseparable from the associated drifts acknowledged to be of glacial origin, and that their curiously mixed assemblage of shells does not represent a contemporaneous fauna.¹ These beds form part of the 'Helvetian' interglacials of Professor Geikie's scheme.

Midland Counties.—In the North Midlands, Mr. R. M. Deeley,² in classifying the complex drifts of the Trent Basin, has sought to explain these deposits as the product of several successive glacial and interglacial epochs, but the correlation of these supposed epochs with those of Professor Geikie is found difficult.³ All except the latest of the deposits classed as interglacial are unfossiliferous; and the evidence for glaciation later than this fossiliferous deposit—an ancient river-gravel of the Derwent containing mammalian remains (hippopotamus, rhinoceros, and elephant)⁴—is very questionable.⁵ The recent work of the Geological Survey in the district, in which I am taking part, confirms Mr. Deeley's opinion that the basin was invaded by ice-lobes from different quarters, which attained their maxima at different times. It is also found that there are areas which apparently lay beyond the reach of these lobes, and remained unglaciated.⁶ In these circumstances, the simplest explanation of the facts seems to be that the marginal area was sometimes exposed and sometimes ice-covered by the different flows in their oscillations during a single prolonged period of glacial conditions. There is no evidence of marine submergence in the district, though the whole of it lies much below the level attained by the shelly 'middle glacial' stratified drifts of the country to the westward.

Farther south, Mr. W. Jerome Harrison, after a lengthy investigation of a wide area centring around Birmingham, finds that the drifts were the product of three great ice-lobes—the 'Arenig Glacier,' the 'Irish Sea Glacier,' and the 'North Sea Glacier'; and he concludes that there has been no marine submergence and that 'the district affords no proof of any "interglacial" period.'⁷

North-western Counties.—The glacial deposits of West Lancashire, Cheshire, and North Wales are essentially analogous to those of the Isle of Man. The supposed 'middle glacial' submergence has figured largely in the voluminous literature of this part of the country; and Professor Geikie, by supposing that certain Welsh and Yorkshire cave deposits of doubtful age are interglacial, and that an undefined part of the glacial sands and gravels indicates interglacial submergence, is able to picture a 'Saxonian' glaciation, a 'Helvetian' mild interglacial epoch with a wide land surface succeeded by marine conditions, and then a later 'Polandian' glaciation from the same quarter as the first.⁸ But the investigators who have studied this district most closely are agreed that the interstratification of the boulder-clay with the sands and gravels is so intimate and so many times repeated that the deposits must have been practically contemporaneous and of common origin; and the differences of opinion that have arisen are on the question whether these drifts as a whole have been deposited by the sea or by land-ice.⁹ The case

¹ 'The Glacial Drifts of Norfolk,' *Proc. Geol. Assoc.*, vol. ix. (1887), pp. 111-129.

² 'The Pleistocene Succession in the Trent Basin,' *Quart. Journ. Geol. Soc.*, vol. xlii. (1886), pp. 437-480.

³ 'The Glacial Succession,' *Geol. Mag.*, dec. iii., vol. x. (1893), pp. 31-35.

⁴ H. H. Arnold-Bemrose and R. M. Deeley, 'Mammalian Remains in Derwent River Gravels,' *Quart. Journ. Geol. Soc.*, vol. lii. (1896), pp. 497-510.

⁵ C. Fox Strangways, *Mem. Geol. Survey*: 'Country between Derby,' &c. (1905), p. 41.

⁶ *Summary of Progress of Geol. Survey for 1905.*

⁷ 'The Ancient Glaciers of the Midland Counties,' *Proc. Geol. Assoc.*, vol. xv. (1898), pp. 400-408.

⁸ *Great Ice Age*, 3rd ed., pp. 367-374.

⁹ e.g. :—C. E. De Rance, *Rep. Brit. Assoc. for 1893*, p. 779; A. Strahan, *Quart. Journ. Geol. Soc.*, vol. xlii. (1886), p. 383; T. Mellard Reade, *Quart. Journ. Geol. Soc.*, vol. xxx. (1874), pp. 35-37; and *ibid.*, vol. xxxix. (1883), pp. 123-127.

for the land-ice hypothesis and for the unity of the glaciation has been admirably summarised by Professor P. F. Kendall.¹

The systematic researches of the late J. G. Goodchild in Edenside,² and of Mr. R. H. Tiddeman in North Lancashire and Yorkshire,³ failed to bring to light any evidence for this great 'Helvetian' break in the glaciation; nor have the later investigations farther southward, among which we may mention those of Professor T. J. Jehu in Pembrokeshire,⁴ and of the Geological Survey in South Wales, shown any other result.

In support of the hypothetical Helvetian land surface in the north-western region, Professor Geikie lays stress upon the discovery of a muddy deposit containing undetermined vegetable remains and diatoms in the boulder-clay near Ulverston, in North Lancashire. This material, penetrated in borings for iron ore, was first described by Mr. J. Bolton,⁵ over forty years ago, as occurring beneath the 'pinel' (boulder-clay) and just above the Carboniferous Limestone; Miss E. Hodgson⁶ shortly afterwards gave reasons for believing that the 'muck' had been introduced into the cavernous top of the limestone by recent streams which drain underground; and eighteen years later Mr. J. D. Kendall⁷ recorded further borings, which seem to show that the material sometimes occurs a few feet above the base of the boulder-clay; but his suggestion that the outcrop of the bed in question may be represented by the submerged forests occurring above the boulder-clay on the foreshore at Walney, Dring, and St. Bees indicates a misapprehension of the evidence. Professor Geikie infers that the great mass of boulder-clay, in one place 70 feet thick, above the 'muck' represents the Polandian boulder-clay, and the bottom clay, rarely more than 3 or 4 feet thick, the Saxonian glaciation; but this reading is quite contrary to the usual relations of the boulder-clays assigned to these epochs; and, indeed, the whole case is too indefinite to carry any weight.

Another peaty deposit to which an interglacial age has been assigned was observed many years ago near Macclesfield by Dr. J. D. Sainter,⁸ but in this instance the bed occurred above all the boulder-clays, and was covered only by a few feet of coarse bouldery gravel, which, from its topographical position, is probably of fluvial origin and of late-glacial or post-glacial age.

Northern Counties.—In Northumberland and Durham, so far as I am aware, no indication of the Helvetian interglacial epoch is forthcoming. The boulder-clays, with their interbedded sands and gravels, are like those of the North Yorkshire coast, and have received similar explanation. Dr. D. Woolcott,⁹ in his recent description of glacial sections in Northumberland, remarks: 'So far as the available evidence . . . goes there does not seem to be anything pointing to an interglacial period or periods. The deposits of sand and sandy clay intercalated in the true boulder-clay are, as a rule, most irregular in position, and vary laterally in thickness.'

Southern England.—In the South of England, beyond the area of actual glaciation, evidence for an interglacial epoch has been brought forward from two or three localities, where deposits of very limited extent, partly of marine and partly of freshwater origin, have yielded a fauna and flora indicative of comparatively warm conditions.

¹ In G. F. Wright's *Man and the Glacial Period* (London, 1892), pp. 145-153, and in H. Carvill Lewis's *Glacial Geology of Great Britain and Ireland* (London, 1894), pp. 394-434.

² *Op. cit.*, and *Quart. Journ. Geol. Soc.*, vol. xxxi. (1875), pp. 55-99.

³ *Quart. Journ. Geol. Soc.*, vol. xxviii. (1872), pp. 471-491.

⁴ 'The Glacial Deposits of Northern Pembrokeshire.' *Trans. Roy. Soc. Edinburgh*, vol. xli. (1904), pp. 53-97.

⁵ *Quart. Journ. Geol. Soc.*, vol. xviii. (1862), pp. 274-7.

⁶ *Ibid.*, vol. xix. (1863), pp. 19-31.

⁷ *Ibid.*, vol. xxxvii. (1881), pp. 29-39.

⁸ *Geological Rambles round Macclesfield* (Macclesfield, 1878), pp. 65-67.

⁹ *Quart. Journ. Geol. Soc.*, vol. lxi. (1905), p. 68.

Of these, the most important is a marine deposit containing a molluscan fauna of southerly facies, which occurs on the coast of Sussex near Selsey. The case for its interglacial age has been stated by my colleague, Mr. Clement Reid,¹ who observed numerous large erratic boulders resting on a floor of Eocene beds in a temporary exposure on the foreshore, and infers that these boulders represent a period of glacial conditions anterior to the deposition of the bed containing the temperate-climate shells, while a later period of glaciation is inferred from the presence of the 'Coombe-rock,' or chalky rubble, overlying the shell-bed. This interpretation of the section has, however, already been challenged by Professor P. F. Kendall.² The erratics are not seen to pass under the clays with southern mollusca, as there is a gap of about half a mile between the two deposits, so that the succession cannot be proved by direct superposition. But Mr. Reid urges that 'another method is available: to observe the occurrence of material derived from the one stratum and redeposited in the other.' 'No fragments of southern mollusca have yet been found in the erratic gravel,³ but the clays with southern mollusca often contained redeposited erratics. The gravel with erratic blocks is, therefore, the older of the two.' The bed overlying the shelly deposit also contains erratics, and these, too, Mr. Reid considers to be 'redeposited'; but it appears to me that the grounds for this inference are insufficient. By Godwin-Austen,⁴ who had previously described the section, it was considered that the horizon of the boulders was above the shell-bed; and, since the shelly deposit itself does not appear to exceed a few feet in thickness, it is probable that heavy stones dropped on the sea-floor by floating ice would embed themselves in the shelly mud.

Mr. Reid's suggestion that the shell-bed may represent a warm interglacial epoch newer than the glaciation indicated by the Chalky boulder-clay, and therefore newer than the so-called 'middle glacial' of Northern England, or than the Helvetian Epoch of Professor Geikie's scheme, adds further confusion to the issue; and the presence of estuarine and freshwater deposits on the same coast, at West Wittering and at Stone, in Hampshire, also regarded as belonging to the same interglacial episode, raises additional difficulties.

Without entering at length into the matter, I can only state that in my opinion, after full consideration of the records, these South Coast sections do not afford definite proof of a mild interglacial episode.

Some Deposits above the Boulder-clays.—The freshwater deposits at Hoxne,⁵ in Suffolk, and at Hitchin, in Hertfordshire,⁶ classed by Mr. Reid as interglacial, belong to a different category. They occur within the region of actual glaciation, but in both cases it has been proved by Mr. Reid that the beds overlie the Chalky boulder-clay; and there has been no subsequent glaciation of the district. At Hoxne, however, though not at Hitchin, the remains of arctic plants are found in one part of the series, overlying deposits containing temperate plants. It is to be noted, however, that several of the temperate plants occur also in the arctic plant-bed, but are supposed to have been derived from the older deposit.

Under the usual classification of the field-geologist, the whole series would be regarded as late-glacial or post-glacial. At any rate, being above the Chalky boulder-clay, they cannot belong to the supposed middle glacial, or Helvetian Epoch; and as the arctic plant-bed of Hoxne is classed by Mr. Reid⁷ as 'Late

¹ 'On the Pleistocene Deposits of the Sussex Coast.' *Quart. Journ. Geol. Soc.*, vol. xlvi. (1892), pp. 344-61. See also *The Origin of the British Flora* (London, 1899), chap. iv. *et seq.*

² 'The Cause of the Ice Age.' *Trans. Leeds Geol. Assoc.*, pt. viii. (1893), p. 64.

³ Godwin-Austen, however, found southern shells in the Pholas-borings which Mr. Reid assigns to the supposed glacial deposit: *infra cit.*

⁴ R. Godwin-Austen 'On the Newer Tertiary Deposits of the Sussex Coast.' *Quart. Journ. Geol. Soc.*, vol. xiii. (1857), pp. 40-72.

⁵ 'Report of Committee on Relation of Palæolithic Man to the Glacial Period.' *Rep. Brit. Assoc. for 1896*, pp. 400-415.

⁶ 'The Palæolithic Deposits at Hitchin and their Relation to the Glacial Epoch.' *Proc. Roy. Soc.*, vol. lxi. (1897), pp. 40-49.

⁷ 'Origin of the British Flora,' *supra cit.*, p. 53.

Glacial,' along with other plant-beds with a similar flora which lie directly upon the glacial drift in many parts of Britain, it is difficult to know where, in the English glacial sequence, we are to place the supposed interglacial epoch represented by the temperate plant-beds of Hoxne and Hitchin.

From such deposits we regain at the most a mere fragment of the whole flora of the time; and I think there is a danger that we lay too much weight upon accidental instances of preservation. Is it not possible that the northern flora lingered for some time in suitable places alongside the re-advancing temperate plants? That some minor oscillations of climate have occurred during post-glacial times may be admitted; but, so far as my experience has reached, I have not yet seen any evidence for a general reversal of climatic conditions after the accumulation of the Upper boulder-clay of eastern and western England.

SCOTLAND.—The Scottish evidence still remains to be considered, and I must confess to a certain timidity in venturing across the Border into this stronghold of the 'Interglacialismus,' especially as my personal acquaintance with the Scottish drifts is slight. But, armed with the experience gained south of the Border, I will attempt the raid.

On the eastern side of Scotland the drifts broadly resemble those of the east of England; while in western Scotland they appear to be more nearly akin to those of Wales and the west of Ireland; with this difference, that there is more plentiful evidence for local valley-glaciers during the waning stages of the Glacial Period.

The evidence for the Helvetian Epoch of deglaciation in Scotland is even more confused and indefinite than in England. Some sporadic patches of peaty and silty material associated with the boulder-clay are supposed to represent a continuous land surface during an epoch when previous ice-sheets had entirely melted away; and similar patches of marine origin are interpreted as the product of a Helvetian submergence with which this interglacial episode terminated. But the evidence is so widely scattered and so diverse in character that it leaves us sceptical, in spite of the admirable skill with which its arrangement into the scheme is effected.

The land deposits, almost without exception, were observed in temporary exposures of small extent that are not available for further study, and in several instances doubt has arisen as to their exact relations with the boulder-clay. The 'elephant-bed' at Kilmaurs, Ayrshire, appears generally to have underlain the boulder-clay, and was originally supposed to be pre-glacial, though on other evidence it is regarded as intercalated between two boulder-clays where both happen to be present.¹ The plant-bed near Airdrie, Lanarkshire, as we learn from the careful description of the late James Bennie,² occurred in wisps in the boulder-clay, and was evidently displaced; and, moreover, as in other of these Scottish plant-beds, the flora is of arctic character. There are, in fact, according to Mr. C. Reid, only three localities at present known in Scotland where plants indicative of a temperate climate have been discovered in beds supposed to be intercalated with boulder-clay, viz., Cowden Glen (Renfrew), Redhall, and Hailes (both near Edinburgh), and in each case Mr. Reid has found such anomalous results in his critical examination of the plant remains said to have been obtained from the deposits that, in spite of his usual willingness to adopt the Interglacial hypothesis, he has been led to doubt the evidence for their 'interglacial' position.³ Professor J. Geikie, it is true, has challenged Mr. Reid's results;⁴ and as it is stated that the Cowden Glen section has been obliterated for many years, the Hailes interglacial deposit long since removed, and the Redhall quarry now obscure, there seems no likelihood of further evidence on either side; which is the more to be

¹ *Great Ice Age*, 3rd ed., pp. 133-135.

² 'On the Occurrence of Peat with Arctic Plants in Boulder Clay at Faskine, near Airdrie.' *Trans. Geol. Soc. Glasgow*, vol. x. (1894), pp. 148-152.

³ 'On Scottish Interglacial Deposits.' *Geol. Mag.*, dec. iv., vol. ii. (1895), pp. 1-3.

⁴ 'Scottish Interglacial Beds' (letter). *Ibid.*, pp. 283-284.

regretted in view of the curious circumstance, already commented on, that not a single interglacial peat-bed has ever been detected in all the length of our unrivalled coast sections. As the matter stands, we are, I think, justified in regarding these Scottish land deposits as an insecure foundation for the wide-reaching conclusions which have been drawn from them.

The hypothetical Helvetian submergence of Scotland rests on similar evidence to that which has been already discussed in the case of the English and Irish drifts. Its limits are not marked by any shore-line, and, indeed, are acknowledged to be uncertain by Professor Geikie himself. Some patches of marine sediments, containing a molluscan fauna that is generally distinctly boreal, have been found, sometimes beneath, sometimes above, and sometimes intercalated with the boulder-clay; but it is especially noteworthy that these patches all occur along the outer margin of the country, contiguous to the sea-basins, and that a belt of shelly boulder-clay, denoting the dispersal of pre-existing marine deposits, occupies a similar position in many places. From my knowledge of the conditions under which the patches of marine detritus occur in the Basement Clay of East Yorkshire, I think it most probable that the shell-beds at Clava, Inverness-shire, and in Kintyre,¹ which lie at or near the base of the boulder-clay, represent the disturbed sea bottom of early glacial times; while that at Chapelhall, near Airdrie, appears to have been a very small isolated patch in the boulder-clay, as no further trace of it was found in the search carried out by a Committee of the Association. These beds are certainly inadequate as proof of a mild interglacial submergence.

In Eastern Aberdeenshire and the neighbouring coast-lands the drifts have been indefatigably studied by that honoured veteran among glacialists, Mr. T. F. Jamieson.² The general succession of the drifts is remarkably similar to that in East Yorkshire, and the evidence for the mild Helvetian Epoch is almost exactly that which we have already considered in England, Ireland, and the Isle of Man.

'*Neudeckian*' (Third Interglacial), '*Mecklenburgian*' (Fourth Glacial), '*Lower Forestian*' (Fourth Interglacial), '*Lower Turbarian*' (Fifth Glacial), '*Upper Forestian*' (Fifth Interglacial), and '*Upper Turbarian*' (Sixth Glacial) Epochs.

According to the terminology usually adopted by British geologists, the Glacial Period came to an end with the final disappearance of the confluent ice-sheets from our lowlands, and the events which followed are classed as Post-glacial. But the latter period has been sufficiently long to cover some extensive changes in the relative distribution of land and sea in Western Europe, accompanied by modifications of climate tending on the whole toward progressive amelioration. To classify these changes into a further series of three interglacial and three glacial epochs, as Professor J. Geikie has done, is, so far as the British evidence is concerned, mainly a question of personal opinion as to the arrangement of the sequence and the application of terms. As we have already seen, the interpretation of the North European sequence, on which Professor Geikie greatly depends for proof of these later epochs of glaciation, has been challenged abroad even by geologists favourable to the general principle of interglacial epochs; and we are, therefore, the more fully entitled to question its application in this country.

In Scotland, Professor Geikie claims that the '*Mecklenburgian*' glaciation was marked by the reappearance of glaciers in the mountain valleys, and by their later extension over part of the neighbouring lowlands in the form of '*district ice-sheets*.' After these had melted away during the '*Lower Forestian*' interglacial

¹ 'Report on the Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other Localities.' *Rep. Brit. Assoc.* for 1893 (Clava), pp. 483-514; *ibid.* for 1894 (Chapelhall), pp. 307-315; *ibid.* for 1896 (Kintyre), pp. 378-399.

² Mr. Jamieson's latest papers: '*The Glacial Period in Aberdeenshire and the Southern Border of the Moray Firth*,' *Quart. Journ. Geol. Soc.*, vol. lxii. (1906), pp. 13-39, and '*On the Raised Beaches of the Geological Survey of Scotland*,' *Geol. Mag.*, dec. v., vol. iii. (1906), pp. 22-25, contain an excellent descriptive summary and discussion of the glacial sequence.

time, there is supposed to have been a regrowth of valley-glaciers that came down to sea-level during the 'Lower Turbarian' stage. Then another melting away marked the 'Upper Forestian,' followed by a fresh appearance of glaciers in the glens of the higher mountain groups during the 'Upper Turbarian' glacial epoch.

But all the phenomena on which this scheme is built seem explicable on the hypothesis of a gradually waning glaciation, during which there were occasional local advances of the mountain-glaciers in their glens, due to temporary increase of snowfall. We have already discussed the probability that the growth of the individual ice-sheets was largely influenced by the local impact of snowfall under changing meteorological conditions, and it seems equally probable that similar changes, in reverse order, accompanied the waning of the same sheets.

Indeed, from the study of recent glaciers, it has been shown that the presence of separate moraines need not indicate separate stages of advance in the ice. In discussing the influence of englacial débris on ice-flow, the late Professor Israel C. Russell has the following pertinent remark: 'The considerations . . . lead to the suggestion that a series of terminal moraines in a formerly glaciated valley, or a similar succession of ridges left by a continental glacier, are not necessarily evidences of repeated climatic oscillations, but may have been formed during a uniform and continuous meteorological change favourable to glacial recession. That is, a débris-charged sheet may retreat for a time, then halt, and again retreat, owing to its terminus becoming congested with foreign material, in response to a climatic change which would cause a glacier composed of clear ice to recede continuously and without halts.'¹

Professor Geikie states his case for the 'Mecklenburgian district ice-sheets' with intrepid but unconvincing persuasiveness.² He acknowledges that no interglacial deposits of the preceding Neudeckian epoch have been recognised in Britain, and bases his argument upon the relation of the hill-drift to that of the lowlands. Into the intricacies of this argument it is impossible for me to enter, but there is one point which requires particular notice. The shelly boulder-clay around Loch Lomond is held to represent the Mecklenburgian glaciation, and its marine detritus to have been derived from a sea-floor belonging to the '100-foot raised beach,' which is supposed to mark an early stage of the same glacial epoch. But, as Mr. T. F. Jamieson³ has shown, there is no valid reason for regarding this boulder-clay as newer than the bulk of the shelly boulder-clays of Scotland; it rests directly upon the solid rock, except at one place, where a wedge of blue clay with shells was found beneath it; and no older boulder-clay is known in the district. Even from the original description of the deposit given by Dr. R. L. Jack,⁴ quoted with approval by Professor Geikie, we can gather no other interpretation; for although Dr. Jack thought that the shells were more probably derived from an interglacial than from a preglacial bed, he still regarded the boulder-clay in which they occur as older than the 'great submergence'—*i.e.*, than the Helvetian interglacial epoch of the new classification.

The evidence yielded by the freshwater deposits that overlie the drifts in Scotland, so far as I can judge, runs parallel with that of the similar deposits in Yorkshire and the Isle of Man. The researches of the late James Bennie brought to light several instances in which arctic plants and other remains occur in such deposits, but always at or near their base, and sometimes overlain by higher beds containing a temperate flora. By Mr. C. Reid, who has determined most of the material, these arctic plant beds are classed as 'Late-Glacial,' and the subsequent deposits as 'Neolithic.'⁵

¹ 'The Influence of Débris on the Flow of Glaciers.' *Journ Geol.*, vol. iii. (1895), p. 831.

² *Great Ice Age*, 3rd ed., chap. xx.

³ 'Some Changes of Level in the Glacial Period.' *Geol. Mag.*, dec. v., vol. ii. (1905), pp. 487-488.

⁴ 'Notes on a Till or Boulder-clay with Broken Shells . . . near Loch Lomond, &c. *Trans. Geol. Soc. Glasgow*, vol. v. (1874), pp. 5-26.

⁵ *Origin of the British Flora*, p. 53.

Some evidence for changes of climate in the uplands during post-glacial times has been recently obtained from the study of peat mosses by Mr. F. J. Lewis; and these changes have been arranged according to the scheme,¹ with Professor Geikie's approval,² by supposing that only certain parts of the sequence are represented in some places. Thus, in the Highland mosses (and presumably also on Cross Fell, in Cumberland),³ where arctic plants are found at the base of the peat, it is assumed that earlier beds have been swept away by glaciation; while in the Southern Uplands an additional glacial and interglacial epoch are supposed to be represented. But as in all cases the peats lie above the glacial drifts, their suggested classification into five stages, ranging from the 'Mecklenburgian' to the 'Upper Turbarian,' seems highly speculative; and it has yet to be decided whether the changes indicated by the plants are so great as to fulfil the requirements of the hypothesis. In any case, it is not likely that many British geologists will be found willing to regard the hill peats as other than post-glacial.

Summary.

My subject has proved unwieldy; and in merely sketching its outlines I am uneasily aware that I have overstepped the usual bounds of an Address. My conclusions—if the term be applicable to results mainly negative—are as follows:—

1. In the present state of opinion regarding the glacial sequence and its interpretation in North Europe, it is premature to attempt the arrangement of the British drifts on this basis.

2. No proof of mild interglacial epochs, or even of one such epoch, was discovered during the examination of certain typically glaciated districts in England, Ireland, and the Isle of Man; and the drifts in these areas yielded evidence that from the onset of the land ice to its final disappearance there was a period of continuous glaciation, during which the former sea-basins were never emptied of their ice-sheets.

3. The 'middle glacial' sands and gravels of our islands afford no proof of mild interglacial conditions or of submergence. In most cases, if not in all, they represent the fluvio-glacial material derived from the ice-sheets.

4. The British evidence for the Interglacial hypothesis, though requiring further consideration in some districts, is nowhere satisfactory. Most of the fossiliferous beds regarded as interglacial contain a fauna and flora compatible with cold conditions of climate; and in the exceptional cases where a warmer climate is indicated, the relation of the deposits to the boulder-clays is open to question.

5. The British Pliocene and Pleistocene deposits appear to indicate a progressive change from temperate to sub-arctic conditions, which culminated in the production of great ice-sheets, and then slowly recovered.

6. During the long period of glaciation the margins of the ice-lobes underwent extensive oscillations, but there is evidence that the different lobes reached their culmination at different times, and not simultaneously. The alternate waxing and waning of the individual ice-sheets may have been due to meteorological causes of local, and not of general influence.

Let me add, in closing, that it would have been a more gratifying task if, instead of probing into these outstanding uncertainties, I had chosen to deal only with the many and great advances that have been made during the last twenty-five

¹ 'The History of the Scottish Peat Mosses and their Relation to the Glacial Period.' *Scottish Geogr. Mag.*, vol. xxii. (1906), pp. 241-252; see also *Trans. Royal Soc. Edinburgh*, vol. xli. (1905), part iii., No. 28.

² 'Late Quaternary Formations of Scotland.' *Zeitschrift für Gletscherkunde*, vol. i. (1906), pp. 21-30.

³ F. J. Lewis, 'Interglacial and Postglacial Beds of the Cross Fell District.' *Rep. British Assoc.* for 1904, pp. 798-799.

years in the domain of British glacial geology. With these advances we have, indeed, reason to be well satisfied. But the necessity for further knowledge is insistent; and it is useless to set about the solution of our intricate problem until we have all the factors at command. Even then—'Grant we have mastered learning's crabbed text, Still there's the comment'—and, as I have tried to show, the comment may raise more difficulties than the text itself.

The following Papers and Reports were then read:—

1. *On the Geology of the Country round York.*
By Professor P. F. KENDALL, M.Sc.

2. *Report on the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, &c.*—See Reports, p. 313.

3. *The Lower Palæozoic Rocks of Pomeroy.* By WILLIAM G. FEARNSIDES.

The Pomeroy district was originally monographed by Portlock between 1838 and 1845, and has since been neglected. Its Lower Palæozoic succession includes both Ordovician and Silurian rocks, and rests unconformably upon a much older series of hornblendic and pyroxenic gneisses and schists, into which masses of granite were intruded in pre-Silurian time.

The succession may be tabulated thus:—

- C. CORRYCROAR GROUP.—Tarannon (Gala Facies).

Variable green and grey flags and shales, with purple and green grits and conglomerates. (*Undivided.*)

- B. LITTLE RIVER GROUP.—Llandoverly (Birkhill Facies).

Lime Hill Beds.

Black, blocky, micaceous mudstones, with light-coloured calcareous bands. Zone of *Monograptus Sedgwickii*, with sub-zone of *Petalograpti*.

Mullaghabuoyah Beds.

Variable grey shales and flaggy shales, with pyritous spots and a few dark bands. Zone of *Monograptus triangulatus*.

Edenvale Beds.

Smooth, grey shales with black mudstone bands. Zone of *Monograptus tenuis*.

Upper Slate Quarry Beds.

Dark cuboidal mudstones, hard and calcareous. Zone of the *Dimorphograpti*.

Lower Slate Quarry Beds.

Soft, blue-grey, papery, micaceous flags. Zone of *Diplograptus modestus*.

Crocknagargan Beds.

Smooth, grey, pyritous shales. Zone of *Cephalograptus acuminatus*.

- A. DESERTCREATE GROUP.—Ashgillian (Drummuck Facies).

Tirnaskea Beds.

(*Upper.*) Smooth, banded, green and dark mudstones. Zone of *Dicellograptus anceps*.

(*Lower.*) Tough, blocky, calcareous grits. Zone of *Dicellograptus complanatus* and *Phacops mucronatus*.

Killey Bridge Beds.

(Upper.) Soft, calcareous, grey mudstones, with *Remopleurides* and *Diplograptus truncatus*.

(Lower.) Soft, ferruginous, blue or yellow mudstones, with numerous *Trinucleus* and *Ampyx*.

Bardahessing Beds.

(Upper.) Hard, calcareous flags and grits, with *Lichas*, *Phacops hibernicus*, *Staurocephalus*, &c., and *Strophomena*.

(Lower.) Softer, uncompacted grits, sandstones, and conglomerates, with large *Strophomena* and occasional *Orthis*.

The Desertcreate Group finds its closest parallel in the Drummuck beds of Girvan, while the Little River Group is most like the Birkhill shales of Moffat. The whole series is overlain unconformably by the Dingle beds of the local Old Red Sandstone, and with that formation has been folded into a remarkable series of shallow isoclines, trending a little south of east and north of west, and having a general southerly pitch. The total thickness of the Desertcreate and Little River Groups together does not exceed 500 feet.

4. *Recent Exposures of Glacial Drift at Doncaster and Tickhill.*

By H. CULPIN and G. GRACE, B.Sc.

Reference was made to the wide area of the well-known Boulder-till at Balby, near Doncaster.

A description was then given of an exposure of Boulder-clay obtained in the sinking of the Bentley Coal Pit, two miles north of Doncaster. Here there is 20 feet of clay with boulders of Permian Limestone, Carboniferous Limestones, grits and gannisters, and Coal Measure shale, with *Anthracomya Phillipsi*. The clay is at a depth of 55 feet to 75 feet below O.D., being covered by 80 feet of alluvial clays, sands, and gravels.

Particulars were given of cuttings on the South Yorkshire Joint Railway, which in a distance of four to six miles south of Doncaster makes four exposures of boulder debris, the most southern being at All Hallows Hill, Tickhill. The maximum depth exposed is 20 feet, but this does not reach the base. In the northern cutting the matrix is less clayey than at Balby, but the Tickhill deposit is a typical tough till which is being excavated with the aid of explosives. The boulders are mainly Permian Limestones, ranging up to 12 cubic feet in size, with some Carboniferous grits and gannisters, and fairly numerous Carboniferous Limestones up to 2 feet cube. So far, only three boulders of Lake District volcanic ash have been noted. One of these is a foot cube.

The paper concluded with a reference to the Permian and Carboniferous boulders at Gringley-on-the-Hill, which is ten miles east of Tickhill, and (like the latter) about forty miles south of York.

5. *Report on the Crystalline Rocks of Anglesey.*—See Reports, p. 301.

6. *On Faults as a Predisposing Cause of the Existence of Pot-holes on Ingleborough.* By HAROLD BRODRICK.

Ingleborough Hill consists of a large plateau of Carboniferous limestone about 400 feet in thickness and capped by a cone of Yoredale rocks with a summit of Millstone Grit. On this plateau there are a large number of pot-holes or vertical shafts in the limestone: there are upwards of thirty of these at present known to exist, and it is probable that there are many more still covered with the deposit of glacial drift. Within the last few years many facts have come to light which

prove that many, if not all, of the deeper pot-holes owe their existence to faults. Rift Pot, a pot-hole on the south-east side of the hill, was recently explored and found to extend to a depth of over 300 feet: the first portion consists of a vertical shaft 114 feet deep, the lower portion of which consists of a chamber 130 feet long and 25 feet broad; from the south end of this the pot descends for a distance of about 200 feet with a series of platforms of jambed stones wedged between the walls of a vertical fissure, finally ending in a short passage which at the end is waterlogged. The pot-hole at the surface takes the form of a fissure 60 feet long and from 1 to 7 feet wide. At the northern end of this fissure, within a few feet of the moor level, the east wall is slickensided, and in the main chamber at the foot of the first shaft the east wall is also slickensided over an area 50 feet in length and at least 20 feet in height. At the surface the slickensides occur along successive master-joints while those in the main chamber occur along another master-joint at a horizontal distance of about 15 feet. These slickensides are horizontal, showing that the fault was one of horizontal displacement, and as a careful examination shows that the beds of limestone on either side of the upper part of the pot correspond, it is clear that no vertical movement accompanied the faulting. The slickensides near the surface are coated with clear crystals of calcite which when removed leave the slickensides very clearly marked.

Only one fault is marked on the maps of the Geological Survey: this is a fault which runs from near Horton to God's Bridge, in Chapel-le-Dale. Along the line of this fault are several pot-holes, all of which have their longer axes in the direction of the fault. Sulber Pot, which is about 59 feet deep, and Nick Pot, which receives an inflowing stream, and has recently been explored to a depth of about 80 feet, exhibit no direct evidences of faulting; but Mere Gill, on the other hand, does. Mere Gill consists of a fissure, about 80 yards long, which is bridged in three places by rock. As a rule this fissure is filled with water to within 30 feet of the surface; in times of normal rainfall the water escapes through a tunnel below the water-level which leads in a southerly direction (away from the valley); it then makes two vertical descents of 80 feet each and turns northwards to emerge in the valley near God's Bridge in the direct line of the fault. On the limestone, which is usually covered by the stream falling into the pot, are crystals of calcite. These are very much water-worn, but clearly indicate the existence of a fault.

Gaping Gill consists of a vertical shaft, 365 feet deep, into which the waters of Fell Beck fall. At a depth of about 190 feet is a ledge some 12 feet wide: at this point a fault is very clearly to be seen; the fault has a downthrow of 6 feet to the south. The shape of practically all the pot-holes is a further indication that they have been formed as the result of faults: they are all much longer than they are wide and thin out at each end into a narrow crack. It is also a noticeable fact that they occur in groups and in such positions that it would have been impossible for a stream to form more than one out of several.

7. Notes on the Speeton Ammonites. By C. G. DANFORD.

A residence of several years in the neighbourhood of Speeton has enabled the author to collect many fossils from the clays and shales underlying the Chalk. With regard to the *Ammonitidæ*, his results confirm the general succession given by Pavlow and Lamplugh, and add some further information.

The lowest portion of the Kimmeridge clay which the author has been able to examine in exposures on the shore contains numbers of ill-preserved ammonites of the square-backed *Hoplites* group; while the higher part contains forms of a different type, belonging to the round-backed *Perisphinctes* and allied genera.

In the lower part of the zone of *Belemnites lateralis* ammonites are extremely rare, and the author has no fresh information to offer; but in the upper part they become plentiful. The very globose forms of *Olcostephanus* (*Olc. gravesiformis*, *Keyserlingi*, &c.) occur mainly in the bed D 3 of Mr. Lamplugh's classification, but are usually in bad preservation. The overlying bed, D 2, is perhaps the most interesting of the whole series; at its base both the *Olcostephani* and the *Hoplites* are

very numerous, the former being often in the condition of imperfect phosphatic casts. Above this band the round-backed ammonites entirely disappear, though *Belemnites lateralis* continues to be fairly abundant up to D 1.

It therefore appears that the southern *Hoplites* obtained full possession of the area earlier than their associated southern belemnites of the *jaculum* type, although rare examples of these belemnites occur in the clays below D 2.

The lower part of the zone of *Belemnites jaculum*, besides yielding many *Hoplites*, contains occasional ammonites pertaining to the genera *Holcodiscus* and *Astieria* (of the *Olcostephani*), and also to other genera. The higher beds are occupied by *Olcostephani* of the genus *Simbirskites*, but these beds have of late years been so poorly exposed that no further information can be given regarding the distribution of these forms.

In the zone of *Belemnites brunsvicensis* ammonites only occur at the extreme base, where there are a few examples of one of the *Simbirskites*, and in its uppermost beds, where the genus *Hoplites*, represented by *H. Deshayesi*, reappears associated with forms of the genus *Oppelia*, the whole of the intervening deposits being apparently devoid of these fossils.

In the beds with *Belemnites Ewaldi*, which may prove to be a distinct zone between the *brunsvicensis* and *minimus* zones, no ammonites have as yet been detected, but in the *minimus* zone *H. interruptus*, Brug., has been found.

The *Criocerata* have been found to exist in most, if not all, the deposits from the uppermost part of the *Belemnites lateralis* zone to the top of the *Belemnites brunsvicensis* zone, and are especially numerous about the middle of the *Belemnites jaculum* zone. They are, however, difficult to determine, being both fragmentary and ill-preserved.

The paper concluded with a list of the species of *Crioceras*, including those described in 'Argiles de Speeton' and those met with by the author, and determined chiefly by Dr. A. von Koenen. This short list might, doubtless, be greatly extended by anyone conversant with the forms of this group.

FRIDAY, AUGUST 3.

The following Papers and Reports were read:—

1. *The Post-Cretaceous Stratigraphy of Southern Nigeria*, W.C.A.
By JOHN PARKINSON, B.A., Principal of the Mineral Survey.

This preliminary account of the post-Cretaceous stratigraphy of Southern Nigeria is the result of work carried out by the Mineral Survey between the winter of 1903 and the summer of 1906.

In adopting the following stratigraphical succession the author wishes it to be understood that the country is densely forested and only partially mapped. In descending order the beds are as follows:—

1. Alluvium of rivers and lower terraces.
2. Benin Sands.
3. Ijebu Beds.
4. Lignite Series.

Four separate areas are described:—

- a. The Central Province (in part).
- b. The Asaba district on the Niger.
- c. The Ijebu district of the Western Province (Lagos Province).
- d. The Calabar district.

The author concludes that stratigraphically the Benin Sands are the most important member of the series; that their deposition marks a very pronounced movement of subsidence, involving nearly all the southern half of the colony; and

that from the succeeding elevation many of the most prominent features of the physiography must date. They consist of ferruginous sands, sufficiently compact to stand in a vertical cliff, occasionally pebbly and false-bedded, but characterised principally by the angularity of their quartz grains and the occurrence of patches of kaolin and fragments of decomposed felspar. The beds contain muscovite, garnet, and various iron oxides.

Between the Cretaceous rocks and the Benin Sands two sets of sediments are claimed to exist, the Ijebu Beds and the Lignite Series. Up to the present they have been found only west of the Niger, though certain ill-developed sections in the Eastern Province suggest that representatives of one or the other may yet be found there. The beds were deposited in fresh or shallow sea-water. So far no volcanic or igneous rocks have been found in any of the beds described.

2. *An Occurrence of Diamonds in Matrix at Oakey Creek, near Inverell, New South Wales.* By Professor T. W. EDGEWORTH DAVID, F.R.S.

Four diamonds were recently discovered in the matrix at the above locality by Mr. A. R. Pike, after prolonged search among the doleritic and diabasic rocks of the district, which he suspected to form the local matrix of the diamond.

The spot was very carefully examined by Mr. E. F. Pittman, Government Geologist of New South Wales, who was quite convinced as to the genuineness of the find. In fact, the internal evidence of the specimens alone is sufficient to prove that the diamonds occur *in situ* in the igneous rock at this mine.

A specimen of the rock containing a diamond of about half a carat in weight, firmly and naturally embedded in it, was exhibited.

The rock may be termed provisionally a hornblende-diabase. It is quite unlike any of the matrix-rock of the South African diamonds, and differs from it especially in general structure, as well as in chemical composition, as the hornblende-diabase of the Inverell district is massive, and not brecciated like the volcanic rock of the diamond-bearing pipes of South Africa.

The hornblende-diabase of Inverell occurs as a dyke 26 feet wide, cutting granite probably of late Carboniferous age; the age of the dyke is unknown, but it is evidently later than the granite, and therefore post-Carboniferous. It is older than the alluvial gravels at the same mine, containing stream tin and alluvial diamonds.

The following analysis of the diamond-bearing hornblende-diabase was made by Mr. J. C. H. Mingaye, Analyst to the Geological Survey, Sydney:—

SiO ₂	50.43	TiO ₂	0.82
Al ₂ O ₃	14.72	P ₂ O ₅	0.22
Fe ₂ O ₃	2.90	SO ₃	0.01
FeO	4.59	Cr ₂ O ₃	0.02
MgO	6.67	MnO	0.03
CaO	7.13	V ₂ O ₅	0.03
Na ₂ O	2.47		
K ₂ O	1.23		100.25
H ₂ O (100° C)	3.82		
H ₂ O (100° C +)	3.49		
CO ₂	1.67	Specific Gravity { I.	2.587
		II.	2.580

Traces (less than 0.01 per cent.) of ZrO₂, Cl, SrO, were found. F, S, NiO, CoO, O, Li₂O are absent.

Fine silver at the rate of 5 dwts. 10 grs. per ton. Fine gold a few grains per ton.

In addition to the diamond embedded in the hornblende-diabase, a second diamond was exhibited, which had been found at the same spot in a heap of the rock, and though no longer actually in its matrix still retained small portions of the base preserved in some relatively deep hollows in its surface. These cavities may possibly be compared to those so frequently found in the quartz-crystals of rhyolites and quartz-porphyrries, and due to the corrosive action of the base. It is,

however, also possible that these superficial and somewhat polygonal hollows in the Inverell diamonds may not be of the nature of negative crystals formed by corrosion, but rather external casts of some mineral once associated with the diamond, but since removed by absorption.

On the corrosion-hypothesis, the diamonds may have crystallised out from the magma of the hornblende-dabase at no very great depth below the spot where they are now found. At all events these cavities, to which attention was first called at this meeting by Professor Bonney, show that the Inverell diamonds did not grow exactly at the spot where they have now been found. The corrosion may have been due to the diamond becoming more fusible as pressure was relieved in the course of its passage upwards from the magma reservoir.

The experiments of Dr. Friedländer, of Berlin, have proved that minute diamonds can be made by stirring a molten magnesian silicate like olivine with a black-lead pencil, and in the Novo-Urei Meteorite diamond has been found associated with magnesian silicates.

In view of these facts it is quite possible, in the writer's opinion, that the hornblende-dabase magma may have been the true parent rock of the Inverell diamonds.

3. *On the 'Cullinan' Diamond.* By F. H. HATCH, Ph.D.

4. *Exhibition of a Remarkable Form of Sodalite from Rajputana.*
By T. H. HOLLAND, F.R.S.

Nearly every discovery of the interesting family of nepheline syenites shows some feature of unusual interest amongst igneous rocks. The latest-discovered occurrence of these rocks in India is remarkable for the presence of a form of sodalite which has the property, apparently unique amongst minerals, of rapidly changing colour in bright daylight from carmine to pale grey or colourless, and of slowly recovering its carmine colour when kept in the dark. The mineral with these peculiar properties was discovered by Mr. E. Vredenburg as a constituent of the pegmatitic veins in a nepheline syenite intruded into the Aravalli schist series of Kishengarh in Rajputana. Along the same belt the sodalite, intergrown with nepheline in the pegmatite veins, is of the common blue variety, and nothing unusual is shown by chemical analysis of either variety. The carmine colour disappears as rapidly on exposure to light in a moist atmosphere as in dry air, in the cold weather as rapidly as at higher temperatures, and under bright electric light as in daylight. The mineral has apparently no effect on a photographic plate, and is not noticeably radio-active. The reappearance of the carmine tint takes place in a few weeks in some specimens, but requires some months' concealment in the dark in others. No explanation has been offered so far to account for this remarkable phenomenon, and the specimens are now exhibited with the hope of obtaining suggestions for a systematic investigation of the mineral.

5. *Fourth Report on the Fauna and Flora of the Trias of the British Isles.*—See Reports, p. 293.

6. *A Contribution to our Knowledge of the Limestone Knolls of Craven.*
By A. WILMORE.

The Craven Lowlands district, between the great faults on the north-east and the grit hills of the Pendle Range on the south is characterised by a well-known series of limestone knolls which have been the subject of much discussion.¹

¹ Tiddeman, *Brit. Assoc. Rep.*, 1899; *Brit. Assoc. Handbook for Leeds and Airedale*, 1890; *Brit. Assoc. Rep.*, 1900; *Geol. Mag.*, January 1901. Marr, *Q.J.G.S.*,

Having worked in the district for some years I venture to make the following suggestions.

I. The words 'knoll' and 'reef-knoll' seem to be differently understood by different workers. It seems to me desirable to drop the term 'reef-knoll.' This term was applied by Mr. Tiddeman to certain extreme members of a series: there is every possible gradation between these and ordinary rounded knolls to which the term would never be applied. Further, the hills so named by Mr. Tiddeman have not all originated in the same way.

II. The following types of knolls may be recognised:—

- A. Those in the grey or bluish-white limestone. Some of these are well-bedded and very fossiliferous; some are obscurely bedded; some are not *apparently* very fossiliferous.
- B. Those in the dark limestones with numerous shales: these knolls are lower and more rounded.
- C. Scar-knolls; truncated folds weathered into semi-rounded and more or less detached masses. These vary from small crags through large peninsular masses to long scar-like ridges. These may be in the white or dark limestones. Sometimes a scar-knoll has been detached from the main mass of a limestone by weathering.

There are gradations of every degree connecting these types.

III. Examples of all these types of knolls occur on one well-defined horizon. They may all be seen striking parallel with the Pendleside shales containing *Posidonomya Becheri*, *Posidoniella levis*, *Aviculopecten papyraceus*, and immediately succeeded by these shales. The succession may be seen at Cracoe and Thorpe, Stockdale, Newsholme, Broughton and Thornton, Downham and Slaidburn.

IV. The knolls are most conspicuous on the margins of the district. They are seen close to the faults at Threshfield, Malham, Attermire, Stockdale, and Bell Busk. Against the grit ridges on the southern side they are well developed at Thorpe and Cracoe, Broughton and Thornton, and near Downham.

It is noteworthy that knoll-like masses are seen *north* of the Grassington branch of the Craven faults, at Craven Moor and near Dibble's Bridge. Here the massive white limestones come up with a much greater dip than is usual north of the faults.

The whole district is much folded. There are well-defined folds with N.E.—S.W. axes intersected by less conspicuous folds parallel to the main Pennine axis. The interference of these fold-systems seems to have directly produced some of the knolls. Folding is seen everywhere, in both the dark and the white limestones; though the well-bedded dark limestones naturally show it best. Minor faults are common, and some of the knolls appear to be due in part to faulting.

V. The more massive knolls of white limestone appear to be due to irregular aggregations of submarine débris. Folding has ridged up these massive limestones, and weathering has intensified the difference between these and the commoner knolls of the district. The smaller knolls are due to folding (as in IV.) and subsequent weathering.

7. *The Faunal Sequence in the Lower Carboniferous Rocks of Westmorland and the adjacent areas of West Yorkshire and North Lancashire.* By Professor E. J. GARWOOD, M.A.

The work with which the present communication deals was begun sixteen years ago in the Shap area, at the suggestion of the late Professor Nicholson; and eleven years ago the general results which had then been arrived at were published in the 'Geological Magazine' in a note by Dr. Marr and the present author.

lv., pt. iii., August 1899; also Dakyns in same number, *Q.J.G.S.* W. Hind and Howe, 'On the Pendleside Group at Pendle Hill, &c.,' *Q.J.G.S.*, lviii., pt. iii., August 1901. Sir A. Geikie, *Text Book of Geology*, 1903, vol. ii. p. 1041.

Dr. Vaughan's Bristol Zones	Sub-zones suggested for Westmorland and W. Yorkshire	Shap District	Ravenstonedale	Arnside Grange District	Kendal	Northern Pennines	Ingleborough and Penyghent
D 2	Up <i>Dibunophyllum</i> aff. ψ <i>Productus latissimus</i>	—	—	Kent's Channel beds	—	Great Limestone Teesdale and Wear-dale	Limestone of Hull Pot Gill
		Ontscar beds, Bampton	(?)	Humphry Head, East side	(?)	<i>P. giganteus</i> beds 'Scar', Limestone <i>Lonsdalia</i> bed Hilton Beck	Hunt Pot beds <i>Dibunophyllum</i> ψ
D 1	Low. <i>Productus giganteus</i> <i>Lonsdalia fort-</i> <i>formis</i>	Up. Knipe Scar Up. Hardendale Nab Up. Orton Scar	(?)	Humphry Head, West side Eggerslack beds	Serpentine Walk Limestone	Up. Melmerby Limestone of Middle Tongue Crae, &c.	Up. Ingleton (White Scars) beds <i>Dibunophyllum</i> ? θ
		Low. Hardendale beds	Waitby beds	Top of Arnside Knott Wharton Crag	Up. Scout Scar beds	Low. Melmerby Limestone Long Fell Musgrave Scar, &c.	<i>Chonetes papilionacea</i> beds, White Scars, Moughton Scar, Horton Scar,
VISEAN	<i>Productus Cora</i> and <i>Chonetes papilionacea</i>	Ashfell Sandstone	Smardale Fell <i>Cyrtina</i> beds	Hampshire beds Low. Wharton Scar Far Arnside, Middlebarrow and Sandside Quarries, Blackstone Pt. Beds	Low. Scout Scar Kendal Fell Kettlewell Quarry <i>Cyrtina</i> bed	? Bituminous limestone beds of Roman Fell	Bellerophon beds Horton, Combe and Craven Quarries
		(?) Ashfell Sandstone					? <i>Paludina</i> Shale, Horton in Ribblesdale, Baseton bed, Ingleton Dale, &c., with <i>Michelina</i> and <i>Caninia</i>
O	<i>Lithostroton basaltiforme</i> and <i>Cyrtina carbonaria</i>	? Water's Farm Series <i>Camero-phoria tsorhyndia</i> bed ? Docker Beck Shap Thorn beds Gasteropod bed	Ashfell beds	Arnside <i>Chonetes</i> beds with <i>Z. cornucopia</i>	Barrowfield and Kettlewell Cave beds	Roman Fell Sandstones, with <i>Syringothyris cuspidata</i>	
Z 2?	<i>Michelina megastoma</i> and <i>Caninia cyindrica</i>	<i>Archæocidaris</i> bed, Kell	Up. Ravenstonedale Limestone, Scandal Beck	Meathop Fell beds	Crag Mollet beds, Brigsteer &c.		
Z 1?	<i>Syringopora</i> aff. <i>reticulata</i>	Top of Shap Abbey cliff	Low. Ravenstonedale Limestone, Scandal Beck	? Low. Meathop beds	—		
		<i>Spiriferina</i> shale <i>Bryozoa</i> bed	Scandal Beck <i>Ciet-stopora</i> bed	—	—		
Shap Abbey Bed							
CHOTHYRS BEDS							
MICHELINIA BED							
PENNINE BEDS							
ALVEOLITES SEPTIOSUS							
D 2							
D 1							

N.B.—(?) placed before a bed implies that the index fossil has not been found in it.

It was there suggested that the Bristol area would probably yield the best results in any attempt to establish a zonal succession in the Lower Carboniferous rocks, and that the corals and brachiopods would yield the most reliable information in this respect.

How thoroughly these suggestions have been justified is proved by the admirable results recently obtained by Dr. Vaughan in the Bristol area; and the time seems ripe for comparing these results with those obtained by the writer in the northern district.

Four broad divisions were originally suggested for the north. In the above table an attempt is made to establish more detailed subdivisions, and a comparison is instituted with the zones adopted by Dr. Vaughan for the Bristol area.

The chief conclusion to be drawn from a comparison of the succession in the two areas seems to be that while the general succession of species found in the northern district is the same as in the Bristol area, some of the zonal forms adopted as most characteristic for the Bristol area are either absent or represented by rare or obscure examples in the north, and certainly would not be chosen as typical subdivisions for that district.

In this table, therefore, the specific names given to the sub-zones in the Bristol area are omitted, to avoid confusion, and the species most characteristic of the northern zones placed in a corresponding column. It will be seen that, as far as the upper and lower zones are concerned, the index fossils are the same; but as regards the *Zaphrentis* zone, the almost complete absence of this characteristic fossil of the Bristol area from the northern district renders another index necessary.

Again, although the beds characterised by *Michelinia megastoma* and *Caninia cylindrica* undoubtedly represent the *Syringothyris* zone of Bristol, the beds in the north are not characterised by *Syringothyris laminosa*. The same remark applies to the zone of *Productus semireticulatus*, which is seldom in the north a characteristic fossil at this horizon. On the other hand, if we take assemblages of fossils at any particular horizon, we can correlate the beds in the two areas with some confidence. The accompanying table giving the general results so far arrived at must be taken as a provisional correlation of the two areas only.

Among the chief points of interest brought out by a study of the faunal succession in the north are (1) the detection of faults in the limestones otherwise obscure; (2) the oscillations of land, producing shallow-water conditions in certain areas in late Tournaisian and early Viséan times, resulting in the absence of the *Lithostrotion basaltiforme* and *Michelinia* beds in the Shap and Ravenstonedale districts, and the substitution of the Ashfell beds; (3) the presence of a land-surface in the Ingleborough district in late Tournaisian times, on which fresh-water deposits containing the remains of *Paludina* were laid down; (4) the dolomitic character of the Tournaisian limestones and the marked silicification of the fossils they contain at certain horizons, especially at the base of the Viséan.

Many interesting features occur, with regard to the palæontological aspect of the succession, which will be found to emphasise the facts and conclusions recently brought forward by Dr. Vaughan for the Bristol district, although on the whole there appears to be an acceleration of the Brachiopod on the Coral fauna in the north.

In conclusion, attention may be called to the presence of a fresh-water Gasteropod fauna at the base of the Carboniferous at Horton in Ribblesdale; the earliest occurrence of freshwater Gasteropods previously recorded in Europe being near the base of the Jurassic rocks in the lower Oolites.

8. *Report on Life-zones in the British Carboniferous Rocks.*

See Reports, p. 302.

9. *Report on the Faunal Succession in the Carboniferous Limestone of the South-west of England.*—See Reports, p. 292.

MONDAY, AUGUST 6.

The following Papers and Report were read:—

1. *Fossil Arthropods of the Coal-Formation.*

By Dr. H. WOODWARD, F.R.S.

In the Coal Measures of England, Wales, and Scotland there occur, in many areas, bands of shale with layers of clay-ironstone nodules, bearing various miners' names, such as 'Pennystone' (ironstone), 'White flat measures,' 'Gubbins,' 'Crawstone bands,' &c.

They occupy more than one horizon in the Coal Measures, and, although alike in their fauna, they cannot be of the same age stratigraphically.

These nodules have long been known to geologists, for when split open they sometimes contain the remains of fishes, crustaceans, insects, myriopods, arachnida, scorpions, king-crabs, leaves of *Neuropteris*, branches of *Lepidodendron*, fruits of *Lepidostrobus*, and shells of *Conularia*, &c.

In Buckland's 'Bridgewater Treatise, 1836,' we find one of the earliest instances recorded of what was supposed, at the time, to be a coleopterous insect, since described by me as *Eophrynus Prestwici*, an arachnid,¹ from the 'Pennystone nodule bed, Coalbrook Dale, Shropshire.

Buckland also mentions that Dr. G. Mantell had discovered, in a similar nodule from Coalbrook Dale, the wing of a neuropterous insect, named *Corydalis Brongniarti*.²

In 1836, Mr. Joseph Prestwich, jun. (afterwards Sir Joseph Prestwich), published his historical paper 'On the Geology of Coalbrook Dale.'³

In plate 12 he figures *Limulus* (afterwards named *Prestwichia anthrax*, *L. (Prestwichia) rotundata*, and *Bellinurus bellulus* (= *L. trilobitoides*), and *Apus dubius*, *Anthropalaemon Grossartii* (Salter).

The Rev. P. B. Brodie (in his 'Fossil Insects') figures a supposed fossil caterpillar of the genus *Bombyx*, from the Coal Measures (now preserved in the Hope Collection at Oxford); it is really a myriapod, *Euphoberia anthrax*.

Dr. Buckland also figures several remains of fossil scorpions from the coal of Bohemia, which have since been more fully made known, together with other fossil Arachnida from that country, by Dr. Anton Fritsch, of Prague.⁴

M. Charles Brongniart's memoir on the Fossil Insects from the Coal Measures of Commeny (Dept. Allier, France) has revealed the richness of this period in air-breathing, tracheated winged insects, comprising Neuroptera, Orthoptera, and Hemiptera.

Dr. Goldenberg early described the Coal Measure insects of Saarbruck, in Rhenish Prussia.

Mr. S. H. Scudder, the eminent American entomologist, has also added enormously to our knowledge of the fossil insects of the Palæozoic Rocks of the United States.

During the past thirty years or more I have myself contributed various papers on Coal Measure insects, which I need not detail here.⁵

The Cockroach (*Blatta*) is most abundant in the Coal Measures. The Dragon-flies attained an enormous size (28 in. across). The Fire-flies (*Fulgoridæ*). . . . The Ephemeridæ, and many Hemiptera. . . . All these insects were either vegetable-feeding or predaceous in their habits. (Coleoptera, Lepidoptera, and Hymenoptera are absent at this early period. There were no honey-flowers in the coal period.

Many kinds of Arachnida, besides scorpions, have been met with; also numerous species of myriapods.

¹ 1871 *Geol. Mag.*, p. 385, pl. 11.

² *Wonders of Geology*, 1839, p. 680.

³ *Trans. Geol. Soc. Lond.*, vol. v. 1840.

⁴ Fritsch, *Palæozoische Arachniden*, Prag 1904.

⁵ *Q. J. Geol. Soc.*; *Trans. Glasgow Geol. Soc.*; *Geol. Mag.*, &c.

For some years past a committee of Littleborough and Rochdale geologists, consisting of Messrs. H. Sutcliffe, Walter Baldwin, W. A. Parker, S. S. Platt, and others, have devoted themselves to the task of working out the beds of shale containing clay ironstone nodules, a portion of the middle Coal Measures at Sparth Bottoms, half a mile south-west of Rochdale Town Hall, in beds estimated to occur 135 feet above the Royley Mine coal-seam.

In the clay ironstone nodules occur well-preserved ferns, *Calamites*, *Sigillariæ*, remains of *Carbonicola acuta* and other Coal Measure lamellibranchs, whilst the number of arthropoda is probably unsurpassed in any locality of this formation.

The first to be noticed was described in 1904 by Messrs. Baldwin and Sutcliffe,¹ under the name of *Eoscorpis spathensis*.

The subsequent finds have been confided by the committee to the author to report upon, and are as follows:—

<i>Prestwichia anthrax</i> , head shields (traces of limbs).	<i>Pygocephalus Cooperi</i> (Sparth and Coal Measures, Dudley).
<i>Prestwichia rotundata</i> , var. <i>major</i> (var. nov.)	<i>Anthrapalæmon Parkeri</i> , H. W. sp. nov., Sparth.
<i>Prestwichia rotundata</i> var? (or (E) <i>Danaæ</i> ?)	<i>Anthracomartus trilobitis</i> (Scudder).
<i>Prestwichia Birtwelli</i> .	<i>Geralinura Sutcliffei</i> , H. W. sp. nov., Sparth.
<i>Bellinurus longicaudatus</i> , H. W. (in Calamite) (sp. nov.)	<i>Mazonia</i> (sp. nov.) Sparth. Cf. <i>Mazonia Woodiana</i> (M. and W.)
<i>Bellinurus Baldwini</i> , H. W. sp. nov.	<i>Xylobius Plattii</i> , H. W. sp. nov., Sparth.
<i>Bellinurus Koenigianus</i> .	<i>Euphoberia spinulosa</i> , Scudder.
<i>Bellinurus Bellulus</i> , König.	<i>Stenodictya lobata</i> ? Brongt. (probably new).
<i>Eurypterus Moysei</i> , Coal Measures (Ilkeston).	

These last named belong to the *Stenodictyoptera* of Brongniart (Proto-ephemera), and represent a very early and generalised group of large flying neuropterous insects, abundant in the Coal Measures of Allier, but very rare here.

The following is a list received from Mr. Robert Kidston, F.R.S., of fossil plants determined by him from the Middle Coal Measures, Sparth, at a horizon 40 yards above the Arley Mine and 40 yards below the Neddy Mine.

<i>Dactylothea plumosa</i> , Artrs. sp.	<i>Spiropteris</i> , sp.
<i>Mariopteris muricata</i> , Schl. sp.	<i>Calamocladus equisetiformis</i> , Schl. sps.
<i>Alethopteris lonchitica</i> Schl. sp.	" <i>charaeformis</i> , Sternt. sps.
" <i>valida</i> , Boulay.	<i>Sphenophyllum cimecifolium</i> , Sthg. sps.
<i>Neuropteris impar</i> , Weiss, sps.	var. <i>saxifragæfolium</i> .
<i>Cyclopteris trichomanoides</i> , Brongt.	<i>Lepidophyllum majus</i> , Brongt.

Fossil of doubtful affinity:—

Vetacapsula Cooperi (Mackie & Crocker).

2. The Jurassic Plants from the Rocks of East Yorkshire.

By A. C. SEWARD, M.A., F.R.S.

Historical.—The work of Young and Bird, entitled 'A Geological Survey of the Yorkshire Coast,' was published at Whitby in 1822. William Bean, John Williamson, and William Crawford Williamson rendered excellent service in the early days of the geological exploration of the Yorkshire coast. Several specimens collected by local naturalists were sent to Adolphe Brongniart, and described by him in his 'Histoire des Végétaux Fossiles,' published in 1828. The publication in 1829 of 'Illustrations of the Geology of Yorkshire,' by J. Phillips, placed the geology of East Yorkshire on a sound scientific basis. Numerous species of Jurassic plants from the Yorkshire coast were figured and described in the 'Fossil

¹ *Q. J. Geol. Soc.*, vol. lx. p. 396, fig. 2.

Flora of Great Britain,' by Lindley and Hutton, which appeared in parts between 1831 and 1837. Important additions have been made to the knowledge of Yorkshire Jurassic plants by W. C. Williamson, Bunbury, Leckenby, Carruthers, Nathorst, and other writers.

Geological.—The East Yorkshire rocks of Lower Oolitic age may be said to consist of three important estuarine series, separated from one another by thin bands containing marine fossils. The majority of the plants have been obtained from the Lower Estuarine Series, which includes the famous plant-bed of Gristhorpe Bay.

Botanical.—I. Equisetales. *Equisetites columnaris* is one of the commonest and most characteristic plants of the Yorkshire Flora. II. Filices. The Ferns are represented by numerous species, including examples referred to the Cyathæaceæ, Osmundaceæ, Schizæaceæ, Dipteridinæ, and Matonineæ. III. Ginkgoales. The genera *Ginkgo* and *Baiera* are both represented by several forms. IV. Cycadales. *Williamsonia*, *Nilssonia*, and *Otozamites* are the most conspicuous examples of this dominant class. V. Conifereæ. The Conifers are less abundant than either the Cycads or Ferns, but the Araucariæ appear to have occupied a prominent position in the vegetation.

The composition of the Yorkshire Jurassic vegetation was compared with that of floras of the same geological age in other parts of the world, and suggestions were made for future work.

3. Report on the Fossil Flora of the Transvaal.

4. The Teaching of Geology to Agricultural Scholars. By Professor GRENVILLE A. J. COLE.

Experience under the Department of Agriculture and Technical Instruction for Ireland has shown that geology appeals strongly to scholars who have been born and bred on country farms. Now that there is a general movement towards the further organisation of agricultural education, it may be opportune to inquire as to how far geology bears upon the problems of the farm, and how far an agricultural student may with advantage be trained as a geologist. The brief paper, of which this is an abstract, is intended, in fact, as a basis for discussion.

The author's views at present are as follows:—

Geology should be an essential subject in the training of instructors for agricultural classes and of heads of experimental stations, but may be regarded as non-essential in the training of farmers' sons for farming work.

The instructor, or itinerant adviser, will have to understand the features of a wide district, and will often have to discover the causes of local differences within that district. His geological training should include the following:—

(i) Rock-forming minerals and their appearance and reactions in the fragmental condition in which they appear in soils. Far more stress should be laid on the physical results of the disintegration of these minerals than on the chemical constitution of the final product, where this is solid. On the other hand, soluble products may be specially dwelt on from a chemical point of view.

(ii) The natural agents of disintegration and accumulation. Origin of soils.

(iii) The origin and structure of common rocks, the microscope being used to show the relation of the minerals to one another before disintegration, and thus to explain how disintegration may proceed in each case. The microscope also impresses the worker with the effective abundance of certain constituents, such as apatite in basic igneous masses, although they may be invisible to the unaided eye.

(iv) The relations of rocks to one another, including questions of drainage and water-supply.

(v) The structure of soils formed from various types of rock; their porosity, fineness of grain, &c., treated experimentally.

(vi) The historic succession of the geological systems, and the principles of stratigraphy, leading up to the reading of a geological map.

The above course, however, should be so systematic and continuous that it need be accompanied by no apologies for the omission or introduction of any special detail. It should be a course of geology suited to agriculturists, but none the less a course in geology. Collection of samples in the field and broad open-air views of the relation of the farm to the country round it are essential features. A field-tour through varied districts should be arranged in conjunction with the teachers of agriculture. Anything that makes the country appeal more to those who work in it is a real gain to the worker; and experience shows that the origin of surface-forms and the past history of a district in geological time have considerable attractions for those who have had their eyes trained, from youth onwards, on a particular piece of country.

While the broadest names should be used for rock-types and for fossil-types of life, yet the necessity for detailed investigation becomes forced on anyone who begins to examine the constituents of a soil. The discussion of minerals is aided by the students' previous knowledge of the elements of chemistry and physics, and the successive faunas can fortunately be dealt with on a basis of zoology. Hence the task of training agricultural scholars in geology is far more agreeable and effectual than is the case with a class of engineers or architects, or with students of those Universities that have not as yet systematised their courses of scientific study.

5. *Notes on the 'Index Animalium.'* By Dr. F. A. BATHER.

6. *The Glacial Deposits of the East of England.* By F. W. HARMER.

The eastern part of Norfolk forms a low-lying area which, could the glacial beds be removed, would seldom rise above the 100-foot contour. This region, therefore, with the Fenland, was the first part of East Anglia to be overrun by the North Sea ice. None of the resulting moraine (similar, for example, to the Contorted Drift of Cromer) is now found in the Fenland, as it has been destroyed by the subsequent advance of the inland ice-stream to which the chalky boulder-clay was due; its former presence is evidenced by the occasional occurrence there of igneous erratics like those found on the Norfolk coast.

At this period, moreover, the North Sea ice must also have advanced over Holderness and the East Lincolnshire plain. A portion of the glacial deposits of those regions may therefore be of equivalent age to the Contorted Drift of Cromer. As, however, the movement of the Scandinavian glacier from north to south must have been gradual, the Contorted Drift may be somewhat newer than the earliest of the glacial beds of North Britain.

Before the deposition of the chalky boulder-clay in East Anglia, the North Sea ice had withdrawn from a great part of that region, and it did not reappear. During its retreat, however, it heaped up a well-marked terminal moraine in the form of a hummocky ridge of drift, in places reaching 300 feet above O.D., extending twelve miles in a S.S.W. direction from Mundesley and Cromer.

The chalky boulder-clay of Suffolk is blue and intensely Kimmeridgian; that of Norfolk is whitish, with a chalky matrix, the boundary between the two being clearly defined. Jurassic boulder-clay, moreover, may be traced across the Fenland from Suffolk into the Lincolnshire plain, while the chalky drift of Norfolk is represented by the chalky clay which is piled against the western slopes of the southern part of the Lincolnshire Wolds to a height of 300 and 400 feet. The behaviour of the last-named drift is instructive. Due to ice crossing the Chalk range through a depression running from north to south in the direction of the present valley of the Bain, it turns suddenly to the S.E. as it approaches the lower ground, instead of overflowing the latter, as it must have done had that course been open to it. The separation between the Jurassic and the Chalky Drift is as clearly marked in Lincolnshire as it is in East Anglia. Produced from the former district to the latter, the line dividing them runs diagonally across the

mouth of the Wash. The author has, moreover, traced a trail of Neocomian erratics for a hundred miles in the same direction from the plain of the Witham to the neighbourhood of Ipswich.

These facts suggest the existence of two confluent but distinct ice-streams travelling, *pari passu*, from N.W. to S.E., that which occupied the Jurassic plain being sufficiently the stronger to thrust on one side the ice descending from the Wolds, diverting it towards Norfolk, mounds of chalky boulder-clay more or less parallel with the escarpment being accumulated between the two as a medial moraine near Horncastle. This view explains why, at the period in question, the North Sea ice was unable to enter East Anglia through the Wash Gap.

The absence of the intensely chalky boulder-clay of South Lincolnshire from the Lincolnshire plain to the W. of Market Rasen, where the escarpment is unbroken and more than 500 feet high, indicates that no ice overflowed the Wolds near that place, nor did any cross from the North Sea to the north of the Humber.

It must therefore have been the region south of that river, and north of Caistor, where the Wolds have been broken up and eroded, which supplied the grey flint and hard chalk (other than that of the Norfolk Drift), which is found everywhere in the chalky boulder-clay over such an enormous area. So prodigious is the total amount of this débris that, were it brought together, it would almost bridge over the depression now dividing the Lincolnshire from the Yorkshire Wolds.

From the Fenland the Great Eastern Glacier fanned out in all directions: to the east over Suffolk, overflowing also the Chalk escarpment from Newmarket to Hitchin, from which it travelled down the dip-slope south-eastward into Essex, and southward towards Finchley and St. Albans. To the south-west it occupied the basins of the Welland, the Nene, and the Ouse with a confluent ice-sheet overspreading the higher ground which separates them. Moving along the strike of the Oxford, clay up the valley of the Ouse, it filled that region with boulder-clay of which the matrix is prevalently Oxfordian; further to the north-west the glacial drift contains a larger proportion of Liassic detritus. The boulder-clay which covers the chalk region immediately below the crest of the escarpment is, as a rule, very chalky, as is the drift to the west of the South Lincolnshire Wolds, and for the same reason, viz., that it was principally the upper and cleaner portion of the ice-sheet which mounted the slopes of the chalk hills. Some Jurassic débris from the Fenland was, however, carried over into Essex, but not enough to give the drift of that region a typically Jurassic character.

Another and an important branch of the Great Eastern glacier passed up the Trent basin. One portion of this climbed the Marlstone escarpment near Grantham, and spread chalky boulder-clay over the high land to the south of that place; another part followed the Trent valley towards the south-west until it met the ice streams of the Dove and the Derwent, the combined ice-flow being thence southwards up the valley of the Soar. Glacial drift containing, on the one hand, Pennine and Mount Sorrel erratics, and, on the other, Jurassic and Cretaceous débris, may be traced for many miles to the south and south-west of Leicester towards Rugby and beyond.

At one time it was believed that the crescentic moraines of York and Escrick represent the greatest extension of the Teesdale ice. Now, the driftless area to the south of York notwithstanding, it is admitted that the ice reached as far as Barnsley and Doncaster; the comparative absence of drift immediately to the south of those places cannot, therefore, have any evidential value in the face of the fact that chalky boulder-clay sets in again in great force still further to the south. The enormous area covered by the moraine of the Great Eastern Glacier, 10,000 square miles in extent, is inconsistent with the view that it can have been wholly due to ice crossing the Wolds at the two places named. We seem, therefore, driven to admit the existence of a great ice-stream continuous from the mouth of the Tees to the Fenland, and from the Pennines to the Yorkshire Moorlands and the Wolds.

The study of the glacial deposits of the East of England does not appear to

support the view that mild interglacial conditions obtained at any time in that region between the deposition of the Cromer Till and the 'cannon-shot' gravels which overlie the chalky boulder-clay.

7. *Lake Oxford and the Goring Gap.* By F. W. HARMER.

Deep borings at Sandy, Newport, and Hitchin, and further west at Stony Stratford, reveal the existence of drift-filled valleys, extending in one case to a depth of 140 feet below sea-level, which were probably connected with that of a pre-glacial river running in a north-easterly direction towards the North Sea. Similar deep borings at Boston, Fosdyke, and Long Sutton may represent the mouth or the seaward extension of such a valley.

As far as the Midland Counties are concerned, the gorge at Goring is unique. At no point between Newmarket, in Suffolk, and Blandford, in Dorset, in the one case, or between Lincoln and Bradford-on-Avon on the other, have the Cretaceous or Oolitic ranges been cut down to the base level of the plains, or does water run through them from one side to the other. Cases similar to that of Goring occur, however, at three of the places named, as well as at Ancaster, and at Ironbridge, in Shropshire. All these are of a distinct type from the dip-slope valleys of the Oolitic and Cretaceous ridges, and they must have originated in a different manner. They have certain striking features in common. Not only do they cut continuously through the ridges, at right angles to the natural drainage of the plains, but they form narrow, sharply cut, U-shaped gorges, having an extremely modern appearance, as distinguished from the older-looking, wider, and more gradually shelving basins of the dip-slope rivers. They are invariably accompanied by lake-like depressions, lower than the general level of the plains, opening into trumpet-mouthed gorges, through which the former are drained.

Dealing first with the gorges at Lincoln and Ancaster, the effect of the advance of the Vale of York glacier to Barnsley and Doncaster, and the obstruction of the gap separating the Yorkshire from the Lincolnshire Wolds by the North Sea ice, as explained in a former paper, must have impounded the drainage of the Trent basin and caused the formation of a lake, the overflow of which could only have escaped over some part of the Lincoln ridge. Unless the Lincoln and Ancaster gaps were already in existence, which seems to the author improbable, some such overflow must have been initiated at that time. The continuous advance of the Trent glacier southwards would eventually have blocked the Lincoln gorge, probably with drift, and the Ancaster gap would have been originated, being afterwards similarly blocked, in its turn, as the ice moved on. These channels, however, would have been reopened successively, and probably deepened, when the ice retreated.

Referring next to the case at Goring, we find scattered over the low country round Oxford a number of isolated hills, generally capped by gravel, the origin of which it is not easy to explain on the hypothesis of the fluvial erosion of the Oxford plain; they present no such difficulty, however, if we regard the latter as the site of an ancient lake, the bottom of which has been gradually lowered.

It has been long known that the gravels in question contain Triassic pebbles, but it is still more important to notice the presence in them, often in great abundance, especially as they are traced towards the gap, of grey Lincolnshire flint.

This flint drift connects itself with a great trail of such detritus extending continuously from Buckinghamshire to the Wolds, being exceedingly common both in the chalky boulder-clay of the Ouse basin and in the gravels into which the latter passes towards the south-west.

The grey flints occur in the highest part of the Oxford gravels, at elevations exceeding 400 feet, as, for example, on a hill immediately to the south-west of that place, and at Basildon, near Goring, above the narrowest part of the gorge. The erosion of the Oxford plain, and of its outlet below that level, cannot, therefore, have commenced until after the arrival of the glacial drift in that region.

Other gravels, also containing Triassic pebbles and Lincolnshire flint, occur at

a somewhat lower level, representing a later stage in the deepening of the bed of Lake Oxford and of the Gap.

The south-westerly advance of the chalky boulder-clay glacier up the Ouse basin, preventing any possible drainage to the east through the Stony Stratford valley, must have caused the formation of a lake over the comparatively low ground which probably then existed between the Chiltern, the White Horse, and the Cotteswold Hills. That the drainage of this lake was from the first in the direction of the present gorge is shown by the presence of flint gravel immediately above it, near the 400-foot contour; it occurs also within it at a lower level. Once started, the drainage has continued to run in the same direction to the present day. The swirl of the water, swollen, especially in summer, by the melting of the ice-sheet which lay close at hand, converging constantly to one point, eventually produced the trumpet-shaped opening which forms such a marked feature of the Gap.

The bottom of the lake, composed of soft Jurassic clay, was gradually deepened, *pari passu* with the excavation of the gorge, the deepest part being always, as shown on the contour maps, near the mouth of the latter, where the erosive power of the escaping water was the greatest.

8. *On the Continuous Glacial Period.* By M. B. COTSWORTH.

The chain of terminal moraines traced by geologists across America and Europe suggest to the author the probability that they were formed when the districts ranged within measurable distance of the Arctic Circle, and that they afford evidence of a gradual shifting of the North Pole.

Corresponding evidences in other parts of the world tend to confirm the author in his opinion that the Polar change is still going on.

The pyramid system of the ancient Egyptians indicates a change of 7° in nearly 6,000 years, which is less than one-tenth of the speed of the equinoctial precession.

The vast ice-cap of Greenland, covering 500,000 to 600,000 square miles, and rising to heights of 8,000 and 10,000 feet, when taken in conjunction with the fact of Dr. Nansen's having crossed the Arctic Sea at corresponding latitudes on the Asiatic side, where the sea-ice only averaged 30 feet thick, suggests to the author that a powerful gravitational force is exerted by the weight of land-ice, which may account for a shifting of the Pole.

TUESDAY, AUGUST 7.

The following Papers and Reports were read:—

1. *Certain Earthquake Relationships.* By JOHN MILNE, D.Sc. F.R.S.

The object of this Paper was to show the statical and dynamical relationships of earthquakes to earthquakes and other phenomena. A very large earthquake in one district has given rise to earthquakes and volcanic eruptions in neighbouring districts. This suggests the breakdown of a statical balance between two rock-folds. The fact that large earthquakes from time to time occur in groups, although their origins may be in distant localities, suggests that the crust of the earth is from time to time generally subjected to unusual stresses. The observation that the frequency of this type of earthquake is roughly proportional to the angular change in direction of the earth's axis in a given interval of time, gives strength to the suggestion. The mass-displacements which accompany megaseismic efforts may be regarded as the cause or as the result of pole-displacements, or both may result from more general influences, as, for example, elastic deformations, bradyseismical activities, erosion and sedimentation, changes in ocean level, and other

molar movements. The part which may be played by earthquakes in displacing the earth's axis will depend upon the position of their origins, their frequency, and the magnitude of the mass moved. A variety of observations have been made which show that a megaseismic displacement is probably very much larger than is usually supposed. A maximum quantity is given at ten million cubic miles moved vertically through a distance of 10 feet. Even if we divide these figures by twenty the molar movements are very large, and these are repeated on the average every week. The cumulative effects of these, unless they are symmetrically distributed in latitude and with regard to the earth's axis, must be very great.

2. *Discussion on the Origin of the Trias.*

(i) *By Professor T. G. BONNEY, Sc.D., LL.D., F.R.S.*

The three subdivisions of the Bunter, east and west of the Pennine Range, apparently unite to the south of it, and thin out as they approach the southern parts of Warwickshire, Staffordshire, and Leicestershire. In Devonshire it thins out in a similar wedge-like manner towards the north and north-east, not reaching the Bristol Channel. The upper and lower members in the northern area are sandstones, generally red, often conspicuously current-bedded, but without pebbles, the grains being frequently wind-worn. The pebble-bed reaches a thickness of 1,000 feet near Liverpool—where, however, sand dominates over pebbles, is about 300 feet thick in the northern part of Staffordshire, and rather overlaps the lower sandstone. The author described the lithological characters of the pebbles, and discussed the reasons for and against deriving them either from a southern or south-western source, like those in the Devon area, or from any region, either exposed or buried, in their more immediate neighbourhood, maintaining a northern origin to be the more probable. The Keuper group, both sandstones and marls, extends without interruption (except for the sea) from Devonshire to beyond Yorkshire on the one hand and to Antrim on the other.

The author considers the Bunter to be a fluviatile rather than a lacustrine deposit, chiefly formed by large rivers. Two of these flowed from a mountain region, of which Scotland and the extreme north of Ireland are fragments, and a third from a similar region to the south-west of Britain. Deposits comparable with the Bunter, and especially the pebble-bed, may be found on the border of the Alps, and these rivers probably traversed (at any rate early and late in the Bunter epoch) arid lowlands, from which, if not absorbed, they may have escaped by some channel now buried under south-eastern England. The Keuper sandstones, as he showed, indicate the setting in of inland sea-conditions, the Red Marls being generally regarded as deposited in a great salt lake. These, like the clays of the Jurassic system, were probably derived from the mountain ranges, which had previously supplied sand and pebbles.

In fact, the physical and climatal conditions of the Trias—and the same perhaps may also be said of the Permian—were probably to some extent comparable with those now existing in certain of the more central parts of Asia, such as Persia or Turkestan.

(ii) *By J. LOMAS.*

In order to test the opinion that the Triassic rocks of Britain have largely been deposited under desert conditions, the chief characters and activities of existing deserts were summarised. No deserts are free from water-action, and they may exist with a comparatively large rainfall, provided it falls in a limited time and is rapidly shed, and not stored up by glaciers, soils, or lakes.

Thus the streams are mostly pluvial, and only occupy their channels temporarily. Blown sand may fill the channels, cover the river gravels, and obliterate all surface traces. Deposits are thus formed, consisting mainly of blown sand with lenticular patches of gravel at various horizons.

The working up of such deposits by wind results in the concentration of the larger stones, while the smaller sand grains are drifted to form dunes.

There is also a tendency for sand grains of a certain size to concentrate in one place, owing to variations in the carrying power of the wind. Beds in vertical order show this feature in a marked degree.

It would appear that one of the dominant characters of desert regions is *concentration*, and this is shown not only in the sifting of materials, but in many other ways. Thus matter brought down by rivers in solution may be deposited round sand grains even during transit, while 'flashes' and shallow pools fed by streams become strongly charged with salts, such as common salt, gypsum, iron-pan, carbonate of lime, and other substances. Mud and drifted vegetation puddles these 'flashes' and prevents the escape of water. On drying, a mud is left strongly charged with salts, marked by desiccation cracks, and covered with the imprints of animals which have come to drink. In many cases the muds of these shallow pools swarm with living *Estheria*.

In many desert localities we find white nodules, consisting of carbonate of lime cementing sand grains. These vary in size from a marble to continuous layers of great extent and 30 feet thick. Carbonate of lime tends to concentrate on land rather than in pools. A third way in which concentration shows itself is in the clustering of organisms round the pools where water is more or less permanent.

Applying these principles to the Trias, the existence of a great spread of river-borne material, the origin and disposition of which had been dealt with by Professor Bonney, may be assumed.

The pebble beds of the Midlands may be the coarse concentrates of such a deposit, while the pebble beds of Lancashire and Cheshire may represent comparatively unaltered fluvial deposits, augmented and thickened by the addition of the finer material from the Midlands.

The Upper Bunter is characterised by the perfect sifting into sizes which the grains of any one bed show.

The Keuper basement-beds contain pebbles and rolled clay nodules, concentrated in places, chiefly in the Midlands.

Some of the pebbles are *dreikanter*. The Lower Keuper may represent a pluvial phase, following the arid conditions of the Bunter.

The Keuper Sandstone contains inclusions of marl with increasing frequency as we ascend from the base. The marl bands are not of very great extent, and are always plano-convex lenses with the convex surface downwards. These may represent the sites of dried-up pools, and it is here that we find footprints, *Estheria*, and other organisms, pseudomorphs of rock salt, &c.

The highest beds represented by the Keuper Marls are composed almost entirely of exceedingly fine splintery quartz dust, the particles not often exceeding $\frac{1}{16}$ inch diameter. Large pools existed at this time with their concomitant beds of salt, gypsum, &c., and *Estheria* and drifted plants are common.

The Keuper Marl may represent the finest residuum of wind-sifting, and may be compared with the loess of Eastern Europe.

(iii) *By* T. H. HOLLAND, *F.R.S.*

Mr. Holland referred to certain phenomena in the Rajputana desert that supported Mr. Lomas's views with regard to the processes of concentration in arid regions. He referred to the separation of the finer angular sands (which were carried bodily in the wind, and became deposited in the north-eastern area when the force of the wind was diminished) from the rounded grains formed by the rolling of grains too heavy to be carried by the wind. With the finer material in the neighbourhood of Bikanir, Mr. La Touche had described the occurrence of undamaged tests of Foraminifera, which must have been carried in the wind some five hundred miles from the Kathiawar coast. Mr. Holland also described the occurrence of the silt bodies filling in hollows in the Archæan surface, having a general plano-convex lens shape, and being charged with salt, beds of gypsum, and

concretionary nodules of carbonate of lime, such as Mr. Lomas had described in connection with the Trias. He was not prepared to admit that the features of the British Trias were due only to wind action; but in the main they were due to the conditions prevailing in desert regions, where, during monsoon seasons, there may be a heavy rainfall for a limited period, with rivers in flood, and all the usual phenomena of river action.

(iv) *By* PROFESSOR GRENVILLE COLE.

Professor Cole said that in dealing with the British Trias they must never forget the great sea eastward, and the likelihood of the establishment of a monsoon system upon its margin. The geographical conditions seemed well suited for this, and an intense rainy season, lasting (say) three months, might easily, year after year, sweep down and redistribute materials which remained dry for the other nine months. Sheets of pebbles, without well-defined water-channels, were compatible in such cases with general evidences of desiccation.

3. *Notes on the Permo-Carboniferous Coal-fields of Australasia.*

By PROFESSOR T. W. EDGEWORTH DAVID, *F.R.S.*

The author called special attention to the following features: Throughout the whole of Southern Australasia the basal rocks of the Permo-Carboniferous System are either glacial tills resting on striated rock-pavements, or are marine beds with abundant ice-transported boulders scattered through them. In New South Wales and Tasmania the Permo-Carboniferous beds contained an important coal-series—the Greta Series—intercalated between the glacial beds of the Lower Marine Series below and the erratic-bearing beds of the Upper Marine Series above.

In New South Wales there is a thickness of not less than 6,000 feet of strata separating two glacial horizons, a fact which proves that the glacial conditions must have been considerably prolonged.

As regards the mode of origin of the seams, nearly all of them repose on under-clays penetrated by more or less vertical *Vertebraria*, and there is a great abundance in the coal of leaves of *Glossopteris* and *Gangamopteris*. Most of the coal-seams, at the time when their development was finally arrested, supported a luxuriant growth of conifers referred provisionally by Mr. Arber to *Dadoxylon*.

Reference was made to the fact that where the Permo-Carboniferous sediments, as in the type-district near Newcastle in New South Wales, attained a considerable thickness (14,000 feet in that case) they had been considerably folded, but where they were thin they had escaped folding.

The curious pseudomorph lately described by New South Wales geologists as 'glendonite,' allied to thynolite and referred to glauconite, is very abundant in the Upper Marine Series of New South Wales. It resembles in some respects the jarrowite described by Professor Miers from Jarrow, and the pseudomorphs dredged from the recent muds in the Clyde river, and referred to gaylussite.

As regards the quantity of coal exploitable in New South Wales, rough estimates have shown that, if seams less than three feet in thickness and coal at a depth greater than 4,000 feet are left out of account, there remain approximately one hundred thousand million tons, and there is probably an equal amount of Permo-Carboniferous coal available in Queensland.

4. *The Problem of the Palæozoic Glaciations of Australia and South Africa.* *By* PROFESSOR J. W. GREGORY, *F.R.S.*

The Upper Palæozoic Glaciations of Australia, India, South Africa, and South America offer one of the most difficult problems in the history of climate. Some of the conceptions of the extent and nature of their glacial beds present such

formidable difficulties that they have inspired appeals to geological catastrophes. The special problem of these deposits is the occurrence of low-level glacial beds in or near the tropics. In Australia there are glacial deposits on at least three horizons—Cambrian, Carboniferous, and Pleistocene.

The Cambrian beds occur east of Adelaide, and range 400 miles north and south. They are interbedded with marine beds with a rich Cambrian fauna.

The Pleistocene glaciers on the mainland of Australia, so far as has yet been fully established, were limited to a few comparatively small glaciers around the summit of Mount Kosciusko, the highest mountain of Australia.

The Carboniferous glaciation of Australia is the most important. The fact of the glaciation is indisputable, and present interest is concerned with the nature and extent of the ice agent. In Victoria this can now be accepted as land ice, working on an irregular land-surface, on both flanks of a mountain range which then extended E. and W. across the State. The glacial beds of New South Wales, West Australia, and India include some that were laid down beneath sea-level. Glacial deposits of the same age occur in South Africa, India, and South America, and possibly also on the eastern flanks of the Urals.

These beds have been represented as part of a once continuous sheet of glacial deposits; but the evidence does not support this view. The glaciation in each case developed from a series of local centres; and the glaciations at all of them were not necessarily synchronous. The glacial evidence in Africa and Australia disappears to the N., ending about the southern tropic; and in the northern hemisphere it begins again at the lat. of 17° 20' N. and increases in strength northwards to Cashmere.

Three chief groups of theories have been advanced to explain this problem: (1) The shifting of the South Pole into Africa (Oldham), or into the Indian Ocean (Penck); but the absence of evidence of any corresponding movement of the North Pole is opposed to this idea. (2) A universal refrigeration of the world, due to a change in the composition of the atmosphere (Arrhenius); but this theory appears to be a chemical impossibility owing to the action of the sea, and is opposed to the facts that require explanation. (3) The geographical theory—local concentrations of snowfall in consequence of a different distribution of land and water. It was claimed in the paper that the agencies appealed to by this theory are adequate to explain the facts: the glaciations were local and sporadic; they were not all synchronous; they were developed on mountainous regions on the borders of the continent of Gondwanaland, in the neighbourhood of warm seas. They occurred where there was an ample supply of moisture from the sea, high mountains to precipitate it as snow, and a distribution of land and water that would have produced a suitable wind system and low summer temperatures. The proved facts of the Gondwanaland glaciation can be explained by the action of existing meteorological forces acting on their present scale.

5. *On the Artesian Boring for the Supply of the City of Lincoln from the New Red Sandstone.* By Professor EDWARD HULL, LL.D., F.R.S.

Down to the present time since the year 1847—when the waterworks were commenced by a public company—Lincoln has depended for its supply of water upon surface streams, impounded into reservoirs and subjected to a filtering process, the quantity dealt with amounting to about 331 millions of gallons a year, with a rainfall of about 25 inches.¹ Needless to say, a supply from such sources was found to be unsatisfactory on the grounds both of quality and quantity. In 1885 Dr. Harrison was requested to report on the former of these subjects, and he produced elaborate analyses, the general result being that, as some of the sources were liable to pollution, the water was unfit for domestic purposes.²

Owing to the rapid growth of the city the conditions became more unfavourable, and it was determined by the Corporation to ascertain whether some better

¹ Average of fourteen years from 1870 to 1884 inclusive.

² *Report respecting Water Supply* (1885).

source of supply might not be available. With this object the late Mr. De Rance, F.G.S.,¹ was instructed by the Corporation to report 'on the probability of obtaining a pure and sufficient supply of water for the city.' Accordingly he presented a report, dated September 15, 1891, containing the results of a prolonged and careful study of the geological conditions, and stating his opinion that a boring of large diameter to a depth of from 1,250 to 1,500 feet at Torksey or Collingham would yield at least a million of gallons per day of the purest water,² also suggesting supplies from the Oolite limestone formation.

This report does not appear to have been immediately acted upon; and nothing was done until the year 1898, when I received instructions to report on 'the probability of obtaining water by boring near the present pumping station, and if so, at what depth, and at what expense.' After a preliminary survey, I recommended a well and boring to be carried down into the New Red Sandstone, which I estimated would be reached at a depth of about 1,400 feet, from which I anticipated a supply of about a million gallons per day, and that the water would rise in the boring and well up to, or nearly to, the surface of the ground by hydrostatic pressure. It will be observed that my conclusions went to verify those of Mr. De Rance, both being founded on well-recognised geological data, and they have now been abundantly borne out by actual experiment.

Not until the year 1901, however, was a contract signed with Messrs. C. Chapman & Son, of Salford, for carrying out this, the deepest water-boring in the United Kingdom. Nor was it till Sunday, June 10, 1906, that the success of the undertaking was demonstrated, when, on reaching the top beds of the New Red Sandstone at a depth of 1,561 feet 6 inches, the water burst in with great force, and (to adopt the words of the newspaper reporter) 'the roaring sound of rushing waters, far below, was distinctly heard at the surface, and was likened by one of the workmen to the rush of the ægir on the Trent when the tides are at their highest.'³ From this time the water steadily rose in the bore and well, which is 1,502 feet in depth, at the rate of 12 feet per hour, until it ultimately reached the surface and overflowed, which event took place on the Wednesday morning following the inburst of the water.

The following are the formations passed through:—⁴

Lower Lias clay	641 feet.
Rhætic beds	52 „
Red marl and sandstone (Keuper)	868 „
	<hr/>
Total	1,561 feet.
	<hr/>

Below the above is the New Red Sandstone and conglomerate, which reaches the surface in a broad tableland of an average of 300 to 400 feet above the sea-level to the north of Nottingham, and constitutes the source of supply for that town and a large district ranging into Yorkshire. At its nearest border it is about 20 miles from Lincoln, and spreads westward to its margin at Worksop—for a distance of 5 or 6 miles—receiving and absorbing (probably) two-thirds of the rainfall over its area. Owing to its extreme porosity, its absolute continuity in the direction of the dip of the beds (there being no faults between), and the constantly increasing hydrostatic pressure of the water in the direction of Lincoln, we have all the conditions for a successful artesian water-supply. A geological map of the district, and a horizontal section from Worksop to Lincoln, were exhibited in explanation of the uprising of the underground water to the surface at Lincoln.

¹ Author of the work *Water Supply of England and Wales*.

² *Report*, p. 19. Torksey is about nine miles north-west of Lincoln, and Collingham about ten miles south-west of the same place. Water from these places would have required to be pumped all the distance to Lincoln.

³ *Lincolnshire Chronicle*, June 16, 1906.

⁴ Kindly supplied to me by Mr. John W. Ruddock, Chairman of the Water Board, Lincoln.

6. *Further Note on the Occurrence of Diamonds in the Matrix in New South Wales.*¹ By Professor T. W. EDGEWORTH DAVID, F.R.S.

7. *Report on the Correlation and Age of South African Strata.*

8. *Report on Geological Photographs.*

9. *Recent Observations at Vesuvius.* By Dr. H. J. JOHNSTON-LAVIS.

WEDNESDAY, AUGUST 8.

The following Papers and Report were read:—

1. *A Criterion of the Glacial Erosion of Lake-Basins.*
By R. D. OLDHAM.

Apart from the question of whether lake-basins can be eroded by glaciers, a criterion by which the possibility of such an origin can be tested is desirable. Such a criterion appears to exist in the fact that, given a glacier and a rock-basin in its bed, one of two things must happen: either the glacier will flow, as a whole, through the basin, or the ice lying in the depression will remain stagnant while the upper layers flow over it. The first must be the case if the rock-basin has been scooped out by the glacier, and a cross section of the valley and lake will show a continuity of the above and under water slopes, with no interruption at or near water-level. In the second case the rock-basin must have originated independently of the glacier, and a terrace will be formed at the base of the moving portion of the glacier, this terrace being partly due to the wearing away of the sides of the valley, partly to deposition of moraine matter brought down by the glacier. The deeper of the Scottish lochs, when tested by the survey being carried on by Sir J. Murray and Mr. Lawrence Pullan, show just such a terrace at or a little below water-level, and this terrace appears to occur constantly in places where the possibility of its having been formed subsequently to the retreat of the glaciers is excluded. If this terrace is of glacial age it would prove that the lake-basins were not scooped out by glaciers, but owe their origin to some other cause.

2. *Notes on the Glaciation of the Usk and Wye Valleys.*
By Rev. W. LOWER CARTER, M.A.

During a recent holiday the author was able to study the glacial deposits of the district to the north of the South Wales coalfield. The gravelly deposits of Old Red Sandstone material which are characteristic of the valley of the Usk between Brecon and Abergavenny (see 'Geological Survey Memoir') have been traced for some distance to the north-east of Brecon and up the valley of the Usk as far as Trecastle. Here the river breaks away from the old 'through' valley, which is continuous to Llandovery and rises in the Carmarthen Fans to the south. On the top of this red drift were found large numbers of erratics of volcanic ash and brecciated limestone, which the author supposes to have been derived from Ordovician outcrops to the west or north-west of the area in question. These blocks, which run up to two tons or more in weight, are found all down the Usk Valley below Trecastle, and over the col towards Llandovery, in the Gwyddrig Valley, as

¹ Included in Abstract, p. 562.

far down as 'Halfway.' The author has traced them on the flanks of the Brecon Beacon as high as Newadd (886 feet) and down to Talybont, where a large one was found close to the canal tunnel (400 feet). At Llangorse they form part of a moraine which dams back the drainage to form Llangorse Lake. They are found in large numbers at Talgarth, and were traced up Cwm Pwll-y-wrach as high as the 800-foot contour. Numbers of smaller boulders were found mixed with Old Red Sandstone material in gravel deposits near Three Cocks Junction, a little stream revealing good sections in mounds of rearranged and roughly bedded drift deposits. No trace of these foreigners was found in the valley of the Wye from Bulth Wells to Three Cocks, nor were any found in fine sections of boulder-clay examined at Llandrindod Wells.

The author hopes to continue the investigation of these deposits, but believes that sufficient evidence has been collected to point to a local glacier at first in each of the valleys of the Usk and the Wye. The Usk glacier was fed from the Carmarthen and Brecon Fans, but appears to have been overridden subsequently by a stream of foreign ice from the direction of Llandovery, bringing the brecciated erratics and pressing down the valley to Llangorse, Talgarth and Three Cocks. It is to the pressure of this foreign ice that he would attribute the overflow of the Old Red Sandstone drift by the Cray Valley, on to the Carboniferous rocks of Penwyllt, and up Dyffryn Crawnon and through the faulted gap of Nant Trefil into the Rhymney and Sirhowy valleys (as reported by the Geological Survey). Among the erratics of the Wye Valley were tough green grits, which were subsequently found quarried at Bulth, but marked on the geological map as 'Greenstone.' Several interesting stream diversions, owing to accumulations of morainic material, were observed. Amongst the more important were the diversion of the Usk from a wide valley to a narrow gorge at Aberyscir by a moraine at Cradog; of the Honddu at 'The Forge,' Brecon, to the glacial gorge which runs below the Priory Church; and the reversal of the drainage of the Afon Honddu and Olchon Brook at Llanvihangel and Pandy by the morainic gravels which block the wide valley between Bryn-aro and Skirrid-fawr, down which these streams no doubt flowed in pre-glacial times to join the Usk at Abergavenny, whereas now they have been diverted into the Monnow, and so reach the Wye at Monmouth.

Only one case of a dry valley which had been a glacier-lake overflow was noted, and that was the little gorge called Cwm Coed-y-cerig, by which the drainage of Grwyne Fawr appears to have been carried off when the lower part of its present valley was obstructed by a lobe of ice from Crickhowell, but it was not cut deeply enough to continue to take the stream when the lobe was withdrawn.

3. *A Silurian Inlier in the Eastern Mendips.*

By Professor S. H. REYNOLDS.

The rocks described are exposed along the crest of the Mendip range from Beacon Hill on the west to near Downhead on the east, a distance of between two and three miles. They consist of tuffs of several types, and of andesitic lavas. The exposures are everywhere surrounded by the Old Red Sandstone, and till recently it seemed probable that the igneous series was of Old Red Sandstone age. About twenty species of Silurian fossils have, however, now been met with in the tuffs underlying the andesitic lava, and show that the rock is either of Wenlock or Llandovery age. In addition to the normal tuffs there are several exposures of a remarkable rock consisting as a rule of well-rounded blocks of andesite, reaching a maximum length of 2 feet, embedded in a typical ashy matrix. The relations of this rock to the others are not yet clear.

Hitherto contemporaneous volcanic rocks of Silurian age have only been clearly recognised at two localities in the British Isles, viz., Clogher Head in Co. Kerry, and Tortworth in Gloucestershire; the Eastern Mendips constitute a third area.

4. *Report on the Erratic Blocks of the British Isles.*5. *On a Section in a Post-glacial Lacustrine Deposit at Hornsea.*
By T. SHEPPARD.

During the past few years the various sections in post-glacial lake-beds on the Holderness coast have disappeared, as a result of the erosion of the cliffs, and it has been exceedingly difficult to obtain details of the various beds in consequence. During the spring of the present year, however, several on-shore gales resulted in a sea-wall in front of the promenade at Hornsea being demolished, behind which was exposed an exceptionally fine series of clays, marls, peat, and gravel, representing the bed of an ancient mere. This was evidently at one time beneath a sheet of water similar to the present Hornsea Mere. Lists of remains of plants, fresh-water shells, coleoptera, &c., were given, and the fauna and flora of the old and modern meres compared.

6. *On the Plain of Marine Denudation beneath the Drift of Holderness.*
By W. H. CROFTS and Professor P. F. KENDALL.7. *Igneous Rocks of the Districts S.W. of Dolgelly.*
By Professor S. H. REYNOLDS.

This paper described a portion of a larger piece of work upon which Mr. Philip Lake and the author have been engaged for the past ten years. The paper dealt solely with the petrography of the rocks, which include the following types:—

- (a) Intrusive diabase and granophyre (eurite);
- (b) Contemporaneous andesite and rhyolite;
- (c) Rhyolitic and andesitic tuff.

The most noteworthy features are:—

- (1) The great sills or laccolites formed of a diabase devoid of olivine or original hornblende.
- (2) The remarkable series of rhyolitic tuffs and of nodular and banded rhyolites.

8. *A Picrite from the Eastern Mendips.* By Professor S. H. REYNOLDS.

A number of loose pieces of this rock have been found by Mr. H. E. Balch, of Wells, in the neighbourhood of the Ebbor Gorge. Pieces were sent to Dr. J. S. Flett and the author, and were recognised as augite-picrite. Probably the rock forms an intrusion in the Carboniferous Limestone, but is nowhere exposed at the surface, being covered up by the dolomitic conglomerate—the basal deposit of the Trias in the south-west of England. The pieces found were probably pebbles in the conglomerate.

9. *On the Forms of Carbonate of Lime in Pearls and the Pearl-Oyster.*
By J. LOMAS.

The author has sought to ascertain the forms of carbonate of lime in pearls and pearl-oyster by determination of the specific gravity and by Meigen's test.

Specific Gravity.—Three pearls were placed in a Sollas' diffusion-column with crystals of calcite and aragonite used as index minerals. They all floated at the same level, below the calcite and just above the aragonite. A flake of clear transparent nacre from a pearl-oyster which had been kept in spirit was next introduced, and this took up almost exactly the same position in the column.

The nacre was then powdered into the finest fragments and reintroduced. The powder settled to a lower position almost corresponding with aragonite. A piece of nacre from a specimen not preserved in spirit was similarly treated and proved to be of the same density as aragonite.

On gently heating a flake of nacre it was found to curl up, thus indicating that we are not dealing with a homogeneous substance.

On dissolving nacre and pearl in weak hydrochloric acid, an organic residue was left in such quantities as to form a spongy cast of the original.

The columnar part of the pearl-oyster gave similar results, and this came to rest in the diffusion-column just above calcite.

The included organic matter may be a sufficient explanation of the fact that the substances examined did not take up positions exactly corresponding with the indices.

This is all the more likely when we find that on powdering the substances and thus separating the carbonate of lime we get results very closely approximating to calcite or aragonite.

On slicing the pearl-oyster shell and examining under the microscope, it is found that the nacreous layer itself is not uniform. Patches of the columnar part are occasionally seen enveloped in the platy layers of the nacre.

Fine sections of pearls failed to show any enclosures of this nature.

Meigen's Test.—Two pearls and several pieces of pearl-oyster were boiled in dilute cobalt nitrate, and the characteristic purple staining was produced in the pearls and nacre, but not in the columnar layer.

These experiments show that fresh pearls are composed of aragonite mixed with organic matter, while the pearl-oyster shell consists of a columnar layer which is calcite, and a nacreous layer which is aragonite.

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION.—J. J. LISTER, M.A., F.R.S., F.Z.S.

THURSDAY, AUGUST 2.

The President delivered the following Address:—

The Life-History of the Foraminifera.

IN the year 1881 the British Association, having completed the fiftieth year of its existence, met again in the city of York, where its first meeting had been held. By way of marking the completion of its first half-century, and also to do honour to the city which had welcomed its initiatory gathering, it was arranged that the president of each section of the Association should be selected from among the past presidents of the whole. At that time botanists and zoologists were not so far specialised into distinct groups as, for better or worse, they have since become, and were still, at any rate for the purposes of the British Association meetings, able to share their deliberations. Section D included, besides that of zoology and botany, the departments of anthropology and of anatomy and physiology, though the two latter had each its own vice-president.

The naturalist who was selected to preside in 1881 over the whole section was the veteran zoologist, Sir Richard Owen. By that time all or nearly all the 434 scientific memoirs which stand to his name in the Royal Society's Catalogue had been written. Those dealing with comparative anatomy and palæontology, and they are by far the greater part, constitute, to quote the words of Huxley, 'a splendid record; enough and more than enough to justify the high place in the scientific world which Owen so long occupied. If I mistake not, the historian of comparative anatomy and of palæontology will always assign to Owen a place next to and hardly lower than that of Cuvier, who was practically the creator of those sciences in their modern shape.' But Owen's presidential address dealt not with the anatomy or relationships of living or extinct animals, nor with any of those views on 'transcendental anatomy' which have met with less acceptance. The subject selected was the great Natural History Museum at South Kensington, to the planning and establishment of which the energy of his later years was largely directed.

In considering the previous occupants of the chair which I have the honour to hold at this seventy-sixth meeting, I cannot refrain from expressing my sense of the loss which not only his friends, but zoology at large, have sustained in the death, last Easter, of Professor Weldon, the Linacre Professor of Comparative Anatomy at Oxford.

Trained in the pathways of morphology under Balfour at Cambridge, Weldon's energies were, in the later years of his life, devoted to the endeavour to obtain determinations, by means of exact measurements, of the degree of variation from the normal type to which given populations are subject, and, so doing, to find an approximately exact measure of the action of natural selection.

This enterprise and the methods to be employed formed the subject of his address to this Section in 1898, at Bristol: and in 1901, assisted by the high mathematical ability of Professor Karl Pearson, and in consultation with Mr. Francis Galton, he issued the first number of 'Biometrika: a Journal for the Statistical Study of Biological Problems.'

It can hardly be doubted that these and similar methods, if properly applied, will render important service in the elucidation of the problems in which we are all, botanists and zoologists alike, interested; though I may confess, for my own part, that those who prophesy from the biometric side of the church use a tongue which is to me unfamiliar, and that, to my loss, I often go away unedified.

It may appear presumptuous in one who thus confesses his inability to grapple with the mathematical intricacies involved in the application of this method if he attempts to offer anything in the nature of advice to those who use it. Nevertheless I do venture—it may be in the 'insolence of office'—to urge that the old adage should be borne in mind recommending that before beginning culinary operations it is advisable first to catch your hare—in other words, to make sure that the problem you seek to elucidate is sound from the standpoint of biology before bringing a formidable mathematical apparatus into action for its investigation.

Apart, however, from any misgivings on the propriety of the occasions on which this weapon has been used, there can be no question that, properly applied, the biometric method is a potent addition to the biological armoury, and in the victories that it achieves Weldon will be remembered as the leader of those who foresaw its usefulness and forged it.

Not the least memorable of the lessons he has left us, is the eager and strenuous manner in which he did the work, in many fields of activity, which his hand found to do. And while we thus deplore his loss on our own account, as biologists and as friends, our respectful sympathy goes out, I am sure, towards the home where his endeavours found such skilled and devoted assistance.

Two reports of the Evolution Committee of the Royal Society have been published since Mr. Bateson's presidential address on Mendelism, or, as we are now to say, Genetics, two years ago. The coincidence of our meeting with that of the Hybridisation Conference in London, together, as I understand, with the fall of the pea-harvest, will prevent the attendance at Section D of some of the chief workers, though two papers on these lines have been promised us, and some aspects of the matter will, I believe, receive attention at the joint meeting which we hold with the botanists, in which several of the prominent foreign workers at Genetics are expected to take part.

The subject to which I wish to invite your attention is the life-history of a group of lowly organisms, the *Foraminifera*, which belong to a division of the animal kingdom standing apart from all others in the simplicity of the organisation of its members, the Protozoa.

For the last seventy or eighty years the attention of zoologists has been increasingly given to the Protozoa, not only from the interest arising from the particular study of its members, but because, forming as they do a group apart from other animals, and from most plants, they afford a point of view from which to judge of the results on fundamental questions of biology obtained in these more highly developed organisms.

The problems of the relations between protoplasm and nucleus, the significance of the karyokinetic figures and of chromosomes, the phenomena of fertilisation and the differentiation of sex, are all seen more clearly in the light of the results obtained from the Protozoa.

Apart from their interest from this wider standpoint the study of the Protozoa has, as I need hardly remind you, received a great impulse of late years from the discovery that, like the bacteria and their allies, whose action in this respect has been longer recognised, many of them are, when they gain a footing in the body, the cause of disease in man and other animals. An essential step in counteracting

their influence is a knowledge of their life-history and mode of attack. For the proper estimation and interpretation of the facts in the life-history of one organism it is, of course, necessary to be acquainted with its course in allied forms, and in other divisions of the class to which it belongs.

Whether we approach the matter from the philosophical or utilitarian side an essential step is to obtain as completely as possible the life-histories of species belonging to the main groups of Protozoa, worked out in detail. Certain aspects of the Protozoa, such as the shells of the Foraminifera, have received a great deal of attention, and we have much accumulated knowledge on particular phases of the life-histories of many forms, but of how few groups can it be said that we know the life-history of any one species completely! For the last thirty years students of biology have begun their studies with an examination of *Amœba*, yet the life-history of the common forms of amœba, occurring in streams and ditches, still remains, notwithstanding shrewd surmises as to its course—I think Professor Calkins will permit me to say—unwritten.

When, therefore, the progress of knowledge of a group reaches a stage in which the main outlines, at least, of the life-history begin to stand forth clearly, it appears to be a matter of importance, not only to the students of that particular group but, as a standard of comparison, to those of allied groups.

Such a stage has recently been attained in the study of the Foraminifera, and we are now able to sketch with some certainty the general course of the life-history. I have thought, therefore, that the occasion may not be inopportune for me to put the ascertained facts before you, and endeavour to set them in the light of our knowledge of other forms of Protozoa.

The zoologist who for the last twelve years has been pre-eminent in the investigation of the Protozoa, was Fritz Schaudinn, whose early death occurred last June. Beginning his work in F. E. Schulze's laboratory at Berlin, his earlier investigations were directed to the Foraminifera, to the knowledge of which he made important contributions; and three years ago he published an account which, as we shall see, completed the main outline of their life-history. His short papers on *Actinophrys* and various forms of *Amœba* embody observations of the highest interest. Turning to the investigation of the *Sporozoa*, he was soon led to devote his attention more especially to the organisms which produce disease, and his latest achievement was to demonstrate the cause of one of the greatest scourges of humanity.

Much of his work rests on preliminary accounts of investigations which his splendid activity in research left him no time to publish in detail—though we may hope that, in some cases at least, it may be found possible for the fuller accounts to appear. The papers which he did complete, such as those dealing with the Alternation of Generations in *Coccidia*¹ and in *Trichosphærium*,² are not only contributions of first-class merit, but models of research and exposition. In all his work he maintained the broad zoological point of view, and his results on the *Amœba* associated with dysentery are elucidated by those obtained in the study of the Foraminifera. In his insight into the essentials of the problem before him, and his fertility in technical resources, he was, I venture to think, without a rival.

Having chosen so special a subject, I will endeavour first to set forth briefly the elementary facts of the structure of the Foraminifera, in order that those of my audience who are unfamiliar with them may be able to follow.

In the hollows between the ridges on a ripple-marked stretch of sand it may often be noticed that the surface is whiter than elsewhere. On scooping up some of the sand and examining it with a lens it will be found that the whiteness is due in part, no doubt, to fragments of shells of molluscs of one kind or another, but in part to the presence of complete shells of minute size and the most exquisite shapes. Microscopically examined it will be found that in nearly all cases the shells are

¹ *Unt. üb. Generationswechsel bei Coccidien.* Zool. Jahrbücher. Anat. Bd. 13. 1900.

² *Unt. üb. Generationswechsel von Trichosphærium,* Abh. Akad. Berlin. 1899. Anhang.

made up of a number of separate compartments or *chambers*, communicating with one another by one or more narrow passages, and disposed in some regularly symmetrical plan. In some the arrangement is a flat spiral, like that of a watch spring; in others helicoid, like a snail's shell. In some the series of chambers may form a straight or slightly curved line, or they may alternate on either side of a straight axis. There is great variety in the plans on which the shells may be built. They differ, too, in texture; some are transparent, and their walls are perforated by multitudes of minute pores, setting the interior of the chambers in direct communication with the outer world, while in others the walls are semi-opaque, white, and glazed like porcelain, and such perforations are absent. The shells are composed, for the most part, of carbonate of lime contained in an organic 'chitinous' matrix, but in many cases grains of sand are included in the walls.

The planispiral chambered shells present such a close resemblance to the shell of a *Nautilus* that for a long time, notwithstanding their diminutive size, many of them were actually included in that genus, among the cephalopod mollusca. As knowledge advanced the Cephalopoda were divided by D'Orbigny into two groups: the *Siphonifères*, in which, as in *Nautilus*, the Ammonites and *Spirula*, the chambers are in connection by a siphon; and the *Foraminifères*, in which they communicate by pores.

If instead of examining the empty shells left stranded on the shore we take seaweed from shore pools or from shallow water and separate the adherent particles by means of a sieve, similar Foraminiferous shells will be found in the sand which comes through, and these will usually contain the live animal. If glass slides are set in the vessel on the sand, overnight, some of the animals will generally crawl on to them, and they may then be taken out and examined. About these active animals, springing from various points at the periphery of the shell, are multitudes of slender threads, forming fanlike or sheaf-like groups, by which the animal is attached to the substratum, and by which it moves. They are composed of a clear hyaline substance—protoplasm—containing scattered granules. If the animal is killed and the shell dissolved by a weak acid, no organs, such as muscles, stomach, brain, and so forth, are found in the interior, but the same granular protoplasm is found to fill the interior of all the chambers. As in the Protozoa in general, all the elementary functions subserved by the organs of other animals are performed by the undifferentiated protoplasm.

It was not until 1835 that the simple character of the soft parts filling the shells of Foraminifera was recognised by Dujardin. He pointed out that, far from being allied to such highly organised beings as the cephalopod mollusca, they belonged to the simplest forms of animal life, such as *Amœba*, and proposed the name Rhizopoda, which is still in use, for the class containing them.

For many years, however, the correctness of Dujardin's views was matter of dispute. One of the first zoologists to recognise their truth and confirm them was the distinguished Yorkshire naturalist, Professor Williamson, who in 1849 published his memoir 'On the Structure of the Shell and Soft Animal of *Polystomella crispa*,¹ in which, for the first time, the internal structure and the relation between the chambers were correctly described.

In the specimens described by Williamson the shell of *Polystomella* has the following structure. Externally it is a nearly biconvex shell, symmetrical about a median plane, and with a keel-like projection at the margin. In young specimens sharp points like those of a spur often project from the keel. The chambers of which it is composed are arranged in a spiral. They are convex towards the mouth, *i.e.*, on their anterior faces, and concave in the opposite direction. Moreover, each is produced on either side into a process, or *alar prolongation*, projecting towards the axis about which the spiral turns, *i.e.*, towards the convex prominence at the centre of each face. Thus each chamber of an outer whorl of the spiral is placed, as it were, astride of the next inner whorl, and the last whorl of the spire completely hides all the previously formed chambers from view. Careful examination of the anterior face of the terminal

¹ *Trans. Microscop. Soc.*, vol. ii. 1849, p. 159.

chamber reveals a row of foramina along the line where the chamber, including its alar prolongations, rests against the whorl which it bestrides. It results from what has been said that they present a V-shaped line. These foramina are the main openings by which the cavity of the last chamber opens to the exterior. Each chamber of which the shell is composed has been in its turn the terminal chamber, and the openings which then led to the exterior subsequently form communications leading from chamber to chamber. As we trace them back to the earlier chambers they become fewer in number until only a single foramen is found between the chambers. In specimens of the type we are considering a comparatively large globular chamber is the starting point from which growth proceeded. A short passage leads to the second chamber, which has a peculiar shape, being applied to the sphere, produced at one end into a point, and abutting at the other against the third chamber. From this onwards the typical shape is gradually assumed, though in these earlier chambers the alar prolongations are absent. A character of this genus is the presence of the line of pocket-like processes along the posterior margin of the chambers. It was not clear, until Williamson's paper was published, that these ended blindly and did not communicate with the chamber behind. The outer walls of the chambers are traversed by multitudes of pores of extreme minuteness, so that the chambers of the outer whorl have this additional means of communication with the exterior. There is, besides the structures described, a system of canals, lying in the thickness of the walls, and communicating with the chambers, but this need not detain us here.

It results from the structure of such a form as *Polystomella* that in the earliest stage of its existence the whole organism consisted of a single spherical chamber.

It is to be observed that in shells such as *Polystomella* the shape and mode of growth of the organism at all stages of its development are preserved in the central parts of the shell. These early formed chambers may be, in some types of growth, exposed to observation, or they may be, as in this genus, built in and hidden by the overlapping of the subsequent additions. They may then, however, be examined by making sections of the shell, or in the protoplasmic casts of the interior when the shell is dissolved.

The Foraminifera are found living attached to other objects on the sea bottom from shore pools down to great depths, and from arctic to tropical waters. A small group of them lead a pelagic life suspended in the upper layers of the great oceans, from the surface down, as Dr. Fowler's collections from the Bay of Biscay show, to at least 500 fathoms, and their empty shells falling to the bottom constitute the large proportion of the grey 'Globigerina ooze' which in many regions forms the floor of the ocean.

An attractive feature of their study is the abundance with which they are represented in geological deposits, right back to the Palaeozoic period, so that in dealing with them we have that third dimension, the history of the group in the past, wide open to us in which to project our ideas of the course of their evolution.

It was from the study of fossil Foraminifera of the early Tertiary period that the recent advances in our knowledge of their life-history received its impulse.

The later Eocene rocks in many parts of the world abound in discoidal, slightly biconvex Foraminiferous shells, which, from their likeness to coins, have been called Nummulites. The Nummulitic limestones extend across the Old World from the Pyrenees to China, and often attain a thickness of thousands of feet. Visitors to Egypt are familiar with them in the blocks of which the pyramids of Gizeh are built, and the glittering coin-like discs polished by wind and sand and strewn in the desert have attracted notice from remote antiquity.

The structure of a Nummulite is very similar to that of *Polystomella*, but the most spacious part of each chamber lies in the median plane of the shell, while the alar prolongations are very thin and interrupted by supporting pillars of solid shell substance. Hence the median plane is a plane of weakness, and the shell readily splits into plano-convex halves, the broken surfaces exposing a section in the median plane of all the chambers of which it is built.

It has long been recognised that while the great majority of the specimens of Nummulites occurring in a deposit attain a certain moderate size, a few are found scattered through it whose diameter far exceeds that of the others. On examining median sections of the smaller specimens it is usually¹ found that the spiral series of chambers starts from a large and nearly spherical chamber, readily visible to the naked eye, and occupying the centre of the shell, while in the large specimens the spiral series is continued to the centre, where in carefully prepared sections it may be seen to take its origin in a spherical chamber of microscopic size.

Although the two forms were thus found to be associated in the same beds, and to agree with one another closely except in the size to which they grow and in the characters of the central chambers, they were given separate specific names, and attention was called to the puzzling occurrence of these associated 'pairs of species,' a large and a small one, in various deposits.

It was especially by the labours of De Hantken and De la Harpe that this phenomenon was brought to light, the latter palæontologist formulating his 'Law of the association of species in pairs' as follows: 'Nummulites appear in couples; each couple is formed of two species of the same zoological group, and of unequal size. The large species is without a central chamber, the small always has one.' Over sixteen pairs of species of *Nummulites* and the allied genus *Assilina*, associated in this manner have been enumerated.

In the year 1880 Munier-Chalmas brought before the Zoological Society of France his conclusion that the kinds thus associated were not in fact distinct species but two forms of the same species—that, in fact, the species of Nummulites were dimorphic. He also expressed the opinion that the phenomenon of dimorphism would be found to be of general occurrence among the Foraminifera.

To this view, which further investigations have shown to be entirely correct, Munier-Chalmas added a corollary as to the nature of the relation between these two forms, which was wrong. This, however, need not detain us here.² Whether he was set against Munier-Chalmas' views by the error of part of them, or for whatever reason, De la Harpe failed to recognise, before his untimely death which occurred shortly after, the truth which they contained.

Following up the clue which had been found, Munier-Chalmas and his colleague Schlumberger examined the shells of a large series of forms, especially of the *Miliolida*. It was shown, in a fine series of papers, that the phenomenon of dimorphism was present here too, and may find its expression, not only in differences in size of shell and of central chamber, but also in the plan in which the chambers of the two forms are arranged.

While they differ conspicuously—though, as we shall see, in very varying degrees—in the sizes of the initial chamber, it is by no means the case that in all species, as in those of the genus *Nummulites* we have considered, the size attained by the completed test presents so marked a difference. It is, in fact, more usual for the individuals of the two forms of a species to attain approximately the same size on the completion of growth, though standing so contrasted in the size of the initial chambers.

The names *megalosphere* and *microsphere* have been given to the large and the small initial chambers, and the two forms are generally known as the megalospheric and microspheric respectively.

The examination of other groups of Foraminifera has abundantly confirmed the view that the phenomenon of dimorphism is widely prevalent among them.

The Life-history of Polystomella crispa.

Turning now from the consideration of the shells of Foraminifera to the living animals, let us inquire what light has been gained from them on the problem of the significance of the phenomenon of dimorphism.

¹ Usually, because the young of the other type occurs among the smaller specimens.

² Cp. the article by the author on 'Foraminifera' in Lankester's *Treatise on Zoology*, Part I., Fasc. 2, p. 47; and 'On the Dimorphism of the English Species of Nummulites, &c.' *P.R.S.*, vol. 76 B., p. 298.

If a large batch of individuals of *Polystomella crispa* be killed with a reagent which dissolves the shell, though preserving its protoplasmic contents, it will be found, on examining the casts so obtained, that besides those of the type described and figured by Williamson with a comparatively large initial chamber (about $60\ \mu$), and these are by far the most abundant, there are others in which the initial chamber is much smaller (about $10\ \mu$). In other words, megalospheric and microspheric individuals occur in the batch, as among the fossil shells of Nummulites, preserved in the Eocene strata.

On staining them another point of difference appears. A single large nucleus is found in the majority of the megalospheric forms, while in the microspheric a number of small nuclei lie in the chambers most remote from the mouth of the shell.

The result of observations on the living and preserved animals may be briefly stated as follows:—

The Microspheric Form.

The *microspheric form* has many small nuclei, even at an early stage of growth. These nuclei consist of a homogeneous ground substance with many small nucleoli scattered through it. They lie in the chambers near the centre of the shell, and increase in number by simple division. They also exhibit a remarkable phenomenon to which I shall have to recall your attention later. Though several of the nuclei, and especially those that have recently divided, have a rounded contour, many of them are highly irregular in outline, giving off processes which extend in branching irregular strands, staining deeply with nuclear stains, into the protoplasm. Free shreds of such strands lie scattered in the chambers in the neighbourhood of the nuclei, and in large specimens of the microspheric form it is common to find the protoplasm crowded with such deeply staining strands, and with no trace to be found of the rounded nuclei present in the earlier stages. It is difficult to avoid the conclusion that the nuclei, after increasing in number by amitotic division, give off the strands and are ultimately wholly resolved into them.

In a culture of *Polystomella* it is common to find a mode of reproduction which on examination will be found to be that of the microspheric form. It is best followed when occurring in a specimen attached to a glass slide. In the early phases these specimens are distinguished by a great increase in the number of pseudopodia issuing from the shell, so that the latter appears when seen by transmitted light to be surrounded by a milky halo. The protoplasm gradually emerges from the shell until, after some hours, the whole of it has come out and lies massed between the shell and the supporting surface and within the area formerly covered by the halo. The internal protoplasm is darkly-coloured with brown granules, and the whole mass is during this time the seat of involved streaming movements. Clear spots make their appearance, and gradually the protoplasm collects about these and separates into as many spherical masses, which remain connected by a felt of hyaline pseudopodia. Some 200 is a common number to be found. Not long after they have become distinct it may be noticed that each attains a shining coat—the indication that a shell has been formed, a small aperture being left in each for the passage of the pseudopodia. After lying in close contact for some hours, the spheres rapidly and simultaneously draw apart from one another, and within half an hour from the beginning of the movement they are dispersed over a wide area, and each becomes the centre of a system of a pseudopodia of its own.

The whole of the protoplasm of the parent is used up in the formation of the brood of young, the shell being left empty. The process from the first appearance of the halo to the dispersal of the young is complete in about twelve hours.

In a short time the protoplasm which lies outside the aperture of each of the spheres secretes the wall of a second chamber of characteristic shape, and the young individual is then clearly recognisable in size and shape as the two-chambered young of the megalospheric form. Each of the spheres was, in fact, a megalosphere. The microspheric parent has given rise to, indeed it has become, a brood of megalospheric young.

Even before the formation of the megalospheres small rounded, faintly staining nuclei can be seen in stained preparations of the emerged protoplasm, and the latter takes a deep flush owing to the presence of minute particles of chromatin. I am not aware that the origin of these nuclei has been directly observed, but it appears highly probable that they arise by the gathering together about new foci of the staining material distributed through the protoplasm of the microspheric parent.

The Megalospheric Form.

When the megalospheres have become formed their protoplasm contains abundance of irregular chromatin masses, which are at first diffused, and obscure the rounded nucleus near the centre, but I am inclined to think that it is the latter which grows into the large nucleus, the Principal-kern of Schaudinn, which is found throughout the greater part of the life of the megalospheric form.

As growth proceeds and the number of chambers increases the nucleus moves on from chamber to chamber, becoming greatly constricted as it passes through the narrow passages of communication. It grows *pari passu* with the growth of the protoplasm. Numbers of nucleoli are contained in it, lying in a reticulum, and the nucleoli appear to increase in number and to decrease in size as growth advances. Here, too, as in the microspheric form, the nucleus appears to give off portions of its substance into the protoplasm, the path along which it has travelled, through the earlier chambers, being strewn with deeply staining particles of irregular size. Towards the later stages the nucleus loses its compact shape and staining power, and ultimately disappears, and multitudes of minute stained bodies may then be detected scattered through the protoplasm. These become aggregated as distinct nuclei, the protoplasm gathers about them, and they divide by karyokinesis. Then follows a second karyokinetic division, and, the protoplasm having divided correspondingly, the whole contents of the megalospheric shell emerges as a multitude of minute biflagellate zoospores, some 4 μ in diameter.

It so happened that I had been working at the life-history of the Foraminifera at the same time as Schaudinn, though in ignorance of his work.¹ The results that I have set before you on *Polystomella* were obtained by both of us independently of one another, though I had not obtained evidence of more than one division of the spore-nuclei or of the number of the flagella of the zoospores.

The evidence pointed strongly in the direction of the view that the foraminiferal life-history consists of an alternation of generations. While the megalospheric form would, on this hypothesis, arise by a simple vegetative asexual reproduction of the microspheric parent, many considerations seemed to indicate the probability that the microsphere, the initial chamber of the microspheric form, arose by the conjugation of zoospores. In addition to the general probability of the occurrence of a sexual stage somewhere in the life-history, the sizes of zoospore and microsphere fitted in with the view that the latter might be formed by the coalescence of two of the former. Again, the fact of the rarity of the microspheric form in comparison with the megalospheric was comprehensible, on the supposition that, to be able to conjugate, the zoospores must be of different parentage. The point remained, however, a matter of inference until three years ago, when Schaudinn published an account of the processes that he had observed,² turning inference into certainty. Premising that *chromidia* is the name applied to the fragments of staining material distributed in the protoplasm, I will quote the passage:—

‘With the onset of the cold part of the year I observed that many large Poly-

¹ F. Schaudinn, ‘Die Fortpflanzung der Foraminiferen, und eine neue Art der Kernvermehrung,’ *Biol. Centralblatt*, Bd. xiv. N. 4, Feb. 1894.

— ‘Ueb. d. Dimorphismus der Foraminiferen,’ *Sitz. Ber. d. Ges. naturf. Fr. zu Berlin*, 1895, N. 5.

J. J. Lister, ‘Contributions to the life-history of the Foraminifera,’ *Phil. Trans.*, Vol. 186 B. (1895), p. 401.

² ‘Untersuchungen ü. d. Fortpflanzung einiger Rhizopoden,’ *Arb. a. d. Kais. Gesundheitsamte*, Bd. xix. Heft 3, 1903.

stomellas in a vessel were nearly approaching the formation of flagellated spores—that is, that most of the examples which I fixed and stained presented already the complete filling with chromidia, and others had even formed the spore-nuclei. I now took out at random a large number, and, breaking the shells, squeezed out the plasma under a coverslip. In the specimens which had already formed spore nuclei the masses of plasma did not die, but the spores developed quite normally and “swarmed” apart. I was thus not only able to follow clearly with an immersion lens the twice-repeated division of the vesicular nuclei, which occurs very rapidly, but was able repeatedly to observe directly the conjugation¹ of the swarm-cells. The reason that I had not succeeded earlier in this latter, though I had often observed the formation of swarm-cells, is that conjugation only occurs between those arising from separate individuals. I proceeded now as in fertilisation experiments with the eggs of sea-urchins; that is, I crushed a great number of large *Polystomellas* in sea-water, sucked up the expressed plasma in a capillary tube, stirred it about on the cover-glass of a moist chamber, and then had the joy of witnessing many conjugations. The swarm-cells have, as previously stated, two flagella, and a similar wobbling motion to those of *Hyalopus* which I have minutely described; they conjugate in pairs, and cast off their flagella as in *Trichosphaerium*. The karyokinesis occurs very slowly (5–6 hours). When it is finished the nucleus of the zygote soon divides by direct division, and the typical growth begins, with formation of a shell. I have cultivated the young microspheric individuals in a moist chamber as far as the five-chambered stage, when they died, probably from want of nourishment. In most cases the nucleus had repeatedly divided. From these small, many-nucleated microspheric individuals the youngest many-chambered stage described in my earlier publications directly proceeds, so that the life-cycle of *Polystomella* is now complete.’

We are then, at last, able to give with confidence an answer to the question—What is the significance of the phenomenon of dimorphism in the Foraminifera? The answer is, It results from the occurrence of two modes of reproduction in the life-history, sexual and asexual. The megalospheric form is the product of asexual reproduction, the microspheric form arises from the conjugation of two similar zoospores, produced by individuals of the megalospheric form.

In the life-histories of Foraminifera belonging to other families—though not, so far as I am aware, in the Nummulitidae, to which *Polystomella* belongs—there is clear evidence that the members of the megalospheric generation do not always end their existence by the production of zoospores. The protoplasm may emerge from the shells and break up into a brood of megalospheres, as in the reproduction of the microspheric form. In such Foraminifera, therefore, we have to conclude that the megalospheric phase may be repeated in the life-history, and that there may be a succession of megalospheric forms before the sexual stage recurs in the life-cycle. Such a repetition of the asexual mode of reproduction is a common phenomenon in the life-histories of other groups of Protozoa.

In the great majority of cases the size of the megalosphere is much larger than that of the microsphere, and the two forms are thus easily distinguished. There are, however, species (e.g., *Peneroplis*, *Discorbina globularis*) in which the range of variation of the small megalospheres overlaps that of the microspheres, and we have to rely on other characters for discrimination of the two forms.

We must not, however, too hastily apply these results to all the organisms included among the Foraminifera. Wherever there is dimorphism, as expressed in the sizes of the initial chambers, it is clear evidence of the occurrence in the life-history of the sexual and asexual modes of reproduction; and this applies to a wide range of existing species and to fossil forms as far back as the Palæozoic period. The pelagic Foraminifera present a curious and interesting problem in the

¹ I have translated the word ‘Kopulation’ as ‘conjugation,’ which in its biological usage describes the nature of the process more accurately than the English equivalent.

fact that their initial chambers are, at least in the great majority of cases, of uniformly small size, a condition which I suspect to depend on their peculiar mode of life. Again, in the simpler groups (*Gromiidae* and *Astorrhizidae*) the covering appears, in many cases at least, to expand with the growing protoplasm, so that the evidence of their initial condition is not preserved in the shells. In these cases also we have to seek for evidence of the course of the life-history in nuclear and other characters.

Review of Nuclear Characters.

Turning now to the nuclear changes which are found in *Polystomella*, there are many features which are worthy of attention. In their feeding, locomotion, and the mode of forming the shell, in fact in all that concerns their vegetative existence, the megalospheric and microspheric forms are, so far as I am aware, exactly alike; yet in one the economy is dominated by a single nucleus, and in the other by many. Richard Hertwig has compared a uninucleate organism, whether a whole protozoon or a metazoan cell, to an absolute monarchy, and the multi-nucleate organism to an oligarchy, in which the rulers, though many, perform identical functions. In the life-history of *Polystomella* the apparently revolutionary change in government occurs at each reproductive phase, yet the internal and external relations of the state, as far at least as its vegetative life goes, appear to remain unaltered. Why the nucleus of the microspheric form should divide up into a number of daughter nuclei, while that of the megalospheric form remains single, is, to me at least, entirely obscure.

The separation of portions of the chromatic substance of the nuclei, in both forms of the species, and the ultimate resolution of the whole of it into such shreds, dispersed through the protoplasm, appeared at first a puzzling and obscure phenomenon. In metazoan cells, which are advancing to the formation of the reproductive elements, the nuclear divisions occur in regular succession, and the nucleus of a germ-cell may be regarded as the daughter nucleus, granddaughter, great-granddaughter, and so forth, of some other nucleus which went before it. The aphorism *omnis nucleus e nucleo* appears to hold good for the metazoa, but how does it find its application in the case we are considering? Is there any recognition of the hereditary principle when the change of government of our state occurs? Light has recently come on this obscure phenomenon, and, as usual, by the results obtained in other groups of Protozoa. In the introductory essay, *Die Protozoen und die Zelltheorie*, which he contributed to the first number of Schaudinn's 'Archiv' Richard Hertwig drew attention to morphological elements of the protozoan body, distinct from the protoplasm on the one hand and from the formed nucleus on the other, and applied to them the name *chromidia*. They consist of groups of granules or branched strands of a substance staining with the same reagents as the chromatin of the nucleus. In *Actinosphaerium*, in which Hertwig first recognised them, they are normally present in the protoplasm, but their number is increased in particular states of the body in relation to metabolism, as by over-feeding, but also, it was found, by starvation. The chromidia are derived from the nuclei, and indeed under certain circumstances the nuclei may completely resolve themselves into chromidia. A structure present in the body of many shelled Rhizopods, and regarded by Hertwig as of the same nature as the chromidia, is the *chromidial net*. In *Arcella* this lies in the peripheral parts of the disc-like body, and sends reticulate processes into the rest of the protoplasm. Like the chromidia it stains with chromatin stains. Hertwig concludes that in *Arcella* the two or three nuclei originally present may, in a certain phase of the life-history, completely disappear, and that in that case nuclei are formed afresh by the aggregation of chromatin material about new foci in the chromidial net.¹ A similar chromidial net was described by Hertwig in *Echinopyxis*. In the following year Schaudinn² pointed out that the

¹ R. Hertwig, 'Ueb. Encystierung u. Kernvermehrung bei *Arcella vulgaris*,' Kupffer's *Festschrift*, 1899.

² 'Untersuchungen üb. d. Fortpflanzung einiger Rhizopoden,' *Arb. aus d. Kais. Gesundheitsamte*, Bd. xix., Heft 3, 1903.

chromidia and chromidial net of Hertwig were comparable with the strands of staining substance which had been described in the Foraminifera. In tracing out the very interesting life-history of *Centropyxis* he showed that, as in the Foraminifera, the nuclei of the gametes are derived from the chromidial net, while here also the vegetative nucleus disappears. Comparable structures were also shown to exist in *Chlamydomorphys*, a species of *Amœba*, and in *Entamœba*.¹ Schaudinn found that in all the cases investigated by him the nuclei of the gametes are derived from the chromidia, whether diffused or united into a reticulum, and concluded that the chromidia are in fact the substance of the nuclei of the sexual cells. He also instituted a very enlightening comparison with the Infusoria, the macronucleus of which, formed at the division of the zygote nucleus and disintegrating prior to conjugation, he compared with the vegetative nucleus of the Rhizopoda, while the micronucleus finds its homologue in the more or less dispersed chromidia.

By this comparison a number of previously isolated phenomena fall into line. The nuclear apparatus of the Infusoria, differentiated into vegetative and reproductive portions, finds, though not an explanation, at least a parallel in other groups of Protozoa. The scattered chromidia of the Foraminifera are thus connected with the chromidial nets of monothalamous Rhizopods, which present various degrees of compactness, and through them with the definitely rounded Infusorian micronuclei. In the involved streaming movements which precede the separation of the protoplasm of the microspheric parent into the megalospheric brood we may recognise a process of equal distribution of the minutely divided chromidia through all parts of the mass which is about to divide, leading to their transmission in equal portions among the offspring.

The fact that in the Foraminifera, at any rate, the chromidia are directly derived from the vegetative nuclei, though they increase in size independently, is at least some acknowledgment of the hereditary principle in the transmission of nuclear material, though we have at present no evidence whatever to show that the foci about which they gather to form the nuclei of the megalospheres or the mother nuclei of the zoospores are in any way derived from pre-existing nuclei.

Though light appears ahead, it seems to me that we are not yet at liberty to consider ourselves out of the wood. The comparison of chromidia with infusorian micronuclei has brought us a long way from Hertwig's original observations in *Actinosphærium* of the dependence of the formation of the chromidia on states of metabolism; moreover, no evidence has as yet been found that in *Actinosphærium* the gametic nuclei are formed from chromidia.

In comparing the abundant deeply-staining chromidia of the Foraminifera with the Infusorian micronucleus, so poor in chromatin, Schaudinn ascribes the difference to the fact that in the former, as in Rhizopods in general, the formation of the brood (of zoospores) occurs by simultaneous multiple fission, and is connected with the act of fertilisation, so that sufficient chromatin to provide for the nuclear equipment of each of the thousands of zoospores must be ready in the parent as it approaches the reproductive stage. In the Infusoria, on the other hand, where the gametes are the ultimate product of a succession of binary fissions there is never the occasion, at any one time, for so large a store of chromatin in the body.² While admitting that there is much force in this explanation, we may notice that in *Polystomella* the formation of the chromidia begins early in the growth of the microspheric individuals, and they are in my experience very

¹ Calkins in his very interesting observations on *Amœba proteus* also found that the chromidium-like bodies are derived from the vegetative nuclei. See his paper, 'Evidences of a Sexual-cycle in the Life-history of *Amœba proteus*.' *Arch. f. Protistenkunde*, Bd. v. H. 1 (1904).

² I have here considerably expanded what I take to be Schaudinn's meaning. His words are (*l.c.*, p. 553): 'Die Chromidien (of *Polystomella*) entsprechen den in der Ein- oder Mehrzahl vorhandenen Geschlechtskernen oder Mikronuclei der Infusorien. Der Unterschied besteht nur darin, dass wegen der Verknüpfung der Brutbildung mit den Kopulationsvorgängen die Geschlechtskernsubstanz bei *Polystomella* in viel grösseren Quantitäten vorhanden ist, als bei den Infusorien.'

prominently present in full-grown specimens of this generation, although the sexual nuclei are not formed until the next or megalospheric generation has reached maturity. It would appear, therefore, that in *Polystomella* the chromidia are associated with the formation of the nuclei of the reproductive elements, whether these do or do not engage in conjugation.

Goldschmidt,¹ in a very capable review of our knowledge of chromidia, is inclined, on the ground of the apparent difference in relation to the life of the organism between the structures so called by Hertwig, in *Actinosphaerium*, and the chromidial nets and strands of Rhizopods, to the view that two physiologically distinct elements have assumed a morphological similarity and mode of origin. While, retaining the name chromidia for the former, he distinguishes the latter under the name *Sporetia*. It is, however, perhaps somewhat early at present to insist on this distinction. Hertwig's essay has already been most fruitful in results, and we cannot doubt that the nature of the chromidia will be further elucidated now that attention has been directed to them.

The relation in size between the microspheric parent and the members of the megalospheric brood.

There is one other point to which, before concluding, I wish to invite your attention.

In the course of the discussions on the significance of the occurrence of nummulites in pairs, objection was taken to the view that the members of the pair belonged to the same species on the ground that solitary forms—megalospheric or microspheric, unaccompanied by the usually associated sister form—occurred in certain localities. De la Harpe himself, having at first urged this objection, withdrew it; but it is still entertained by some palæontologists, and made the ground for maintaining the view that the members of a pair are specifically distinct.

On looking into the matter I found that two out of the three species of Nummulites which occur in the Bracklesham and Barton beds in the Hampshire basin were only known, so far as published descriptions went, in the megalospheric form, although the corresponding microspheric forms had been found associated with these megalospheric forms on the Continent. It therefore seemed worth while to examine the English beds to see whether they might lend any support to the view I have mentioned. The three English species are the following:—

Nummulites lavigatus (Brug.), megalospheric form '*N. Lamarcki*, d'Arch.'
N. variolarius (Lamk.), microscopic form '*N. Heberti*, d'Arch.'
 and *N. Orbignyi* (Galeotti), megalospheric form '*N. wemmelensis*, d. l. H. and v. d. Br., var. *elegans*, Sow.'

In *N. lavigatus* the microspheric form far exceeds the megalospheric, in the size attained by the full-grown tests, as we have seen to be usually the case with nummulites; but in the other two species the size attained by the two forms is approximately the same. Hence there is in them no external indication of dimorphism, and it is necessary to grind down the little shells to expose the initial chambers in section before they can be referred to one form or the other. The results of the investigation are fully set forth elsewhere,² and I need only say here that on proceeding in this manner with these two species, after grinding down a number of examples which proved to belong to the commoner megalospheric form, I came in each, as I fully expected I should, on examples of the microspheric forms. The English beds, therefore, offer no support to the view that one or other of the forms of a species may occur solitary.³

¹ 'Die Chromidien der Protozoen,' *Arch. f. Protistenkunde*, Bd. v., 1 (1904), p. 126.

² Paper by the author 'On the Dimorphism of the English Species of Nummulites and the Size of the Megalosphere in relation to that of the Microspheric and Megalospheric Tests in this Genus.' *Pro. Roy. Soc.*, vol. B. 76, 1905, p. 298.

³ When the two forms are of different sizes, and the materials of a bed have been rearranged by currents, they may, of course, be differently distributed.

On examining sections of the two forms, megalospheric and microspheric, in the three species, a further point of interest presented itself, namely, that the megalosphere, the initial chamber of the megalospheric form of *N. laevigatus*, was much larger in proportion to the size of the megalospheric shell than the megalospheres of *N. variolarius* or *N. Orbignyi*. I was, therefore, led to examine the proportion in a larger number of forms, and the fine series of nummulites contained in the collection presented by Dr. H. B. Brady to the University of Cambridge gave me the opportunity of doing so on ten species or varieties.¹

In *N. complanatus* the microspheric form attains a diameter of about 2 inches (51 mm.), the megalospheric form a diameter of 5.9 mm. In *N. variolarius* the microspheric form has a diameter of about 1.92 mm. and the megalospheric form of about 1.8 mm.

The result of careful measurement was to show that the volume of the megalosphere is, within narrow limits, proportional to the volume of protoplasm contained, not in the whole megalospheric, but in the whole microspheric test. In other words and in the light of our knowledge of the life-history of the dimorphic Foraminifera, the volume of each of the individual members of a brood of megalospheric young is in *Nummulites* proportional to the bulk of the protoplasm of the microspheric parent out of which they are formed. In Hertwig's essay, above quoted, it is pointed out (p. 30) that in functional cells (not eggs) there is a definite proportion between the mass of a protoplasmic body and the mass of nuclear substance contained in it. If we apply this to the result attained for *Nummulites* it would appear that *the mass both of the protoplasm and its contained nuclear material are in this asexual mode of reproduction proportional to the whole bulk of the protoplasm out of which they are formed.* It would appear to follow that among *Nummulites* the number of the members of the brood in the asexual mode of reproduction ought to be approximately the same in all species.

In the sexual mode of reproduction no such relation holds, for the microsphere in *N. gizehensis*,² the microspheric form of which attains a diameter of 23.7 mm., is hardly larger than that of *N. variolarius*, in which the diameter of this form is, as we have seen, 1.92 mm.

In addition to the structural and other characters, binding the members of 'a pair' of *Nummulites* together, which led de la Harpe to conclude that they belong to the same zoological group, we may now therefore add another—the ratio in volume between the megalosphere of one and the protoplasmic contents of the whole shell of the other.

It would be interesting to find how far this proportion holds good in other genera of Foraminifera. I do not know of any phenomenon precisely comparable with it elsewhere, but the result is so definite that it would appear to be the expression of a general principle.

In conclusion, I may call attention to the difference presented by the species of

¹ The species (or, on the old view, pairs of species) thus examined are:—

<i>N. complanatus</i> , Lamk.,	megalospheric form,	' <i>N. Tchihatcheffi</i> , d'Arch.'
<i>N. perforatus</i> (de Montft.)	" "	' <i>N. Lucasanus</i> , Defr.'
<i>N. Gizehensis</i> (Forsk.)	" "	' <i>N. curvispirus</i> (Menegh.)'
<i>N. perforatus</i> , var. <i>obesus</i>	" "	' <i>N. Lucasanus</i> , var. <i>obsoletus</i> , d. l. H.'
<i>N. laevigatus</i> (Brug.)	" "	' <i>Lamarcki</i> , d'Arch.'
<i>Assilina exponens</i> (Sow.)	" "	' <i>A. mamillata</i> (d'Arch.)'
<i>N. biarritzensis</i> , d'Arch.	" "	' <i>N. Guettardi</i> , d'Arch.'
<i>N. discorbinus</i> (Schlot.)	" "	' <i>N. sub-discorbinus</i> , d. l. H.'
<i>N. Orbignyi</i> (Gal.), var. <i>elegans</i> (Sow.)	" "	' <i>N. Wemmelsensis</i> , d. l. H. and v. d. Br., var. <i>elegans</i> , Sow.'
and		
<i>N. variolarius</i> (Lamk.)	microspheric "	' <i>N. Heberti</i> , d'Arch. and <i>Haime</i> .'

² I have been unable to measure the microsphere in the larger species owing to the cavities of the chambers in my specimens being filled with calcite, and their outlines obliterated.

the genus *Nummulites* in the relative length of life (as indicated by size) of their sexually and asexually produced forms. In *N. variolarius* the life-cycle is apparently equally divided between the two, while in *N. complanatus* the small megalo-spheric form ('*N. Tchihatcheffi*') is almost as much dwarfed by the gigantic microspheric form as, in the life-history of a fern, the prothallus is by a member of the sporophytic generation.

The following Paper and Reports were read :—

1. *The Life-cycle of Protozoa.* By Professor GARY N. CALKINS.

The tendency in modern protozoa study is to regard all work as incomplete which does not fill out the entire series of changes which an organism passes through in its life-cycle, and the whole cycle is becoming more and more important in the characterisation of genera and species, and should hereafter be the sole basis of new species. The definition of protozoa should also convey some expression of the importance of the life-cycle, and I would suggest something like the following: Protozoa are animal organisms consisting of independent single cells, which reproduce by division or spore formation the progeny passing through various phases of activity collectively known as the life-cycle and manifesting various degrees of vitality with accompanying form changes.

The need of some check to the undue multiplication of protozoan species is evident to anyone who consults the annual literature lists, and the confusion that has arisen in classical cases like that of *Plasmodium* and *Polymitus*, *Coccidium* and *Eimeria*, *Trypanosoma* and *Halteridium*, *Paramecium caudatum* and *P. aurelia*, is sufficient to justify more stringent rules. The case of *Paramecium* is particularly interesting because of the wide distribution and the almost universal acceptance of the two species *caudatum* and *aurelia*. The specific differences between them have been emphasised by Maupas, Hertwig, and more recently by Simpson, and are based upon minor differences in form and upon the presence of two micronuclei. In my cultures last year one ex-conjugant from a pair of conjugating *P. caudatum* appeared with all the characteristics of *P. aurelia*, including the form of the body, the double micronucleus, and the greater sluggishness which is supposed to accompany this species. After forty-five generations in culture, in which the organisms were watched day by day, the aurelia characters were lost, and by four months after conjugation the entire race had become *P. caudatum* again, with but one micronucleus and with pointed extremity, and with much greater vigour. There is no doubt that we have to do with but one species in this case.

In any such life-history the organisms pass through phases of vitality which can be compared with the different age periods of the metazoa. Thus we recognise a period of extreme vigour of cell multiplication corresponding to the period of youth of a metazoon: we recognise a period of maturity or of adolescence characterised by changes in the chemical and physical balance of the cell accompanied by well-marked differences in size or in protoplasmic structure and leading to the formation of conjugating individuals with or without sexual differentiation; and, finally, in forms which do not conjugate, we recognise a more or less definite period of old age or senescence ending in death. In many forms, especially in those cases where dimorphic gametes are formed, the period of sexual maturity leads directly into that of old age, and gametes that fail to conjugate are destined to an early death without further multiplication. Thus it is in the majority of sporozoa and in many rhizopods. In ciliates, on the other hand, failure to conjugate, although fatal in the long run, does not involve the immediate death of the organism, and many generations may be formed after this period is passed. In such cases the peculiar cytoplasmic changes which accompany protoplasmic senility can be easily followed.

In most cases the change from youth to middle age in a protozoan life-cycle is too gradual to be made out. In some cases, however, as in *Paramecium* or *Tetramitus*, or *Cercomonas*, &c., the body becomes plastic or amœboid, thus indicating some change in the physical make-up of the protoplasm. In other cases the change

is indicated by nuclear processes, such as the formation of chromidia or of distributed chromatin which, as in rhizopods, may persist through many generations of vegetative individuals, or, as in sporozoa, it may be formed only at the end of vegetative life. In both cases the outcome is the same, and the distributed granules of chromatin form the nuclei of the conjugating gametes. These cell changes are particularly important in a life-cycle, indicating, as they do, the approaching critical period in the history of the race.

We are fully justified, it seems to me, at least for taxonomic purposes, in regarding the 'individual' in protozoa, not as a single cell, but as the whole congeries of cells which are formed from the time of the fertilised gamete to natural death from old age. This sequence of stages constitutes the life-cycle, and the morphological characteristics of each phase must be taken into account to get the only adequate basis for protozoan taxonomy.

As in metazoa, so in protozoa, we can make a clear distinction between the history of the individual in this taxonomic sense and the history of the race, and we can distinguish vital processes that are characteristic of each. The ordinary phenomena of vegetative life of the cell—metabolism in all its phases—have to do with growth and multiplication, and are functions belonging to the life-cycle in its limited sense. The race, which should be considered as a succession of life-cycles, is dependent upon quite a different set of vital activities which are bound up with the maturation and fertilisation of the germ cells. The problems involved here have an interest quite apart from those of the life-cycle, and are no more intimately connected with the phenomena of vegetative life than are they connected in metazoa with growth and differentiation. In any adequate account, however, of a protozoon, these phenomena of the species must be considered, and the biological principles underlying them should be studied even more exhaustively than any of the vegetative processes, for upon them depends the continuity of the species. Two or three points relating to these more deeply-lying racial problems have recently developed from my culture-experiments, and relate for the most part to *Paramecium*.

Although maturation processes have been generally recognised in protozoa, there has been but little work done that can compare even remotely with the elaborate researches on the origin of the maturation chromosomes in the metazoa. Schaudinn, indeed, has described the reduction in the number of chromosomes in *Trypanosoma noctuæ* from eight to four, and speaks of four 'tetrads' in the nucleus of the female cell. The origin of the tetrads, however, is not made out. The origin of the maturation chromosomes in *Paramecium caudatum* has been worked out this last year by one of my students, Miss S. W. Cull and myself. The curious and enigmatical 'crescent form' assumed by the micronucleus is proved to be the stage of synapsis, the chromosomes becoming double at this time by union side by side in typical parasynapsis. The two maturation divisions which follow this preparation are difficult to follow, and the results of our study on this point are not quite ready for publication.

A second point that we have made out relates to an equally important biological principle, viz., the significance of fertilisation. We found that while renewal of vitality was effected in 70 per cent. of all cases of 'wild' conjugating paramecia, only 12 per cent. were successful in conjugating individuals that had been under cultivation for some time. It was proved that diverse ancestry is not a necessary condition, one endogamous ex-conjugant being carried through 379 generations. We also made out that in this supposedly isogamous conjugation there is a definite indication of incipient fertilisation, as in the case of sexually differentiated protozoan or metazoan germ cells, one of the ex-conjugants being much more vigorous than the other. Thus in 41 per cent. (of ninety-three pairs) of the ex-conjugants, only one of the original conjugating pair was represented by progeny at the end of a month; while in 69 per cent. the progeny of one were twice as numerous as those of the other.

A third point that comes from the study of these *Paramecium* cultures relates to the renewal of the cycle or reorganisation without conjugation. Parthenogenesis is known in *Trypanosoma noctuæ* and in *Plasmodium vivax* through the

brilliant work of Schaudinn. The results obtained in these culture experiments show that the same result may be brought about by artificial means, and that a new cycle may be inaugurated by the mere change in chemical composition of the surrounding medium. But they also teach that this result cannot be continued beyond certain limits, and indicate the probability that parthenogenesis has only a limited success, acting merely to postpone or counteract what Hertwig has happily called physiological death. Finally the experiments teach that both physiological and germinal death in protozoa is bound up with the exhaustion of vitality in definite substances in the cell, so that we are as much justified in speaking of germinal and somatic protoplasm of the protozoan cell as of germinal and somatic cells of metazoa.

2. *Report on the Occupation of a Table at the Zoological Station, Naples.*
See Reports, p. 329.

3. *Report on the 'Index Animalium.'*—See Reports, p. 314.

4. *Report on the Colour Physiology of the Higher Crustacea.*
See Reports, p. 325.

5. *Interim Report on the Freshwater Fishes of South Africa.*
See Reports, p. 326.

6. *Sixteenth Report on the Zoology of the Sandwich Islands.*
See Reports, p. 315.

7. *Report on the Madreporaria of the Bermuda Islands.*
See Reports, p. 325.

8. *Report on Zoology Organisation.*—See Reports, p. 326.

9. *Report on the Probability of Ankylostoma becoming a Permanent Inhabitant of our Coal Mines in the event of its introduction.*—
See Reports, p. 315.

10. *Report on the Occupation of a Table at the Marine Laboratory, Plymouth.*—See Reports, p. 325.

11. *Interim Report on the Effects of Sera and Antisera on the Development of the Sexual Cells.*

12. *The Milk Dentition of the Primitive Elephants*
By Dr. C. W. ANDREWS, F.R.S.

13. *The Habits of Tube-building Worms.* By ARNOLD T. WATSON.

The fact has long been known to naturalists that many animals, ranging from the foraminifera, through the bristle-worms (or polychæta), rotifera, crustacea, insects, and mollusca, up to fishes, birds, and certain quadrupeds, are in the habit of building or forming structures (composed of the material with which they are surrounded), either for the protection of their bodies against the attack of enemies, or for some other purpose, such as a temporary home for the reception of their young.

As regards the larger and higher animals the methods by which these structures are produced are fairly well known, but this is not so in the case of the lower forms.

Amongst the latter, probably no group affords more interesting examples of structural workmanship than the polychæte worms. These worms, with very few exceptions, are marine; most diverse in form, and some of them as charming and attractive as the most beautiful flowers. Some of the tube-building worms are sedentary, their tubes being fixtures to the spot, but others travel about freely through the sand or on its surface.

In all cases special means are provided for respiration, which is mainly effected through the skin, the water being drawn through the tube by a peristaltic pumping or a waving action of the body of the worm. As an example of the flower-like form, the lecturer described *Sabella* from his personal observations, and [by means of lantern-slides and a cardboard model] explained its method of tube-formation, the material being collected by the so-called branchial tentacles and applied, by the collar lobes, as a coating on the outside of a secreted tube.

As a guard against the intrusion of an enemy, the mouth of the tube usually collapses, but in one rock-boring species of this family the end of the tube rolls up like the frond of a fern. As an instance of a different form of sedentary worm, the method was fully described by which *Terebella* builds with sand, shells, or gravel the tubes so common on our shores, the free ends of which are terminated by a wonderful arborescent arrangement constructed by the worm with single grains of sand or other material which it finds suitable.

After a brief reference to the immense honeycombed masses with which colonies of *Sabellaria* in many places bind together sandy shores, and to the calcareous tubes formed by the *Serpulids*, the lecturer passed on to the mud-eating errant worms. It is by a worm of this group, the golden-combed *Pectinaria*, that the most beautiful masonry is produced.

The material for formation of these well-known conical sand-tubes is evidently selected with the greatest care and most conscientiously fitted into appropriate positions, no superfluous cement being used to make up for bad workmanship. The second example of this group was *Owenia filiformis*, a worm which constructs a flexible tube by attaching, in an imbricated manner, the flat sand-grains or fragments of shell to a membranous tube secreted by special glands. In this tube, as in a coat of mail, the worm burrows through the sand, its hold on the tube being ensured by an immense number of uncini, or hooks, arranged in bands round the body. A most interesting fact in connection with this worm is that the imbricated formation of the tube has been rendered possible by an extraordinary modification of the structure of the animal itself. The third group comprised worms regarded as carnivorous from the fact that they are provided with formidable jaws; these were exemplified by *Panthalis cerstedi* and certain onuphid worms, all deep-sea forms. *Panthalis* constructs a massive tube by weaving together cobweb-like threads supplied by the glands of the feet, and mingling therewith mud obtained from the sea bottom. The onuphids described formed scabbard-like tubes of shells or flat stones, or secreted tubes of a horny, transparent material, in which they creep about the bed of the sea. The tubes are open at both ends, but the worms defend themselves with considerable mechanical skill against the attacks of enemies by constructing membranous internal valves at each end of the tube (on the principle of the valves in a vein), which, by inrush of the sea water, are closed automatically on retreat of the inmate.

FRIDAY, AUGUST 3.

The following Papers and Report were read :—

1. *Some Results of the Infection of Monkeys with Guinea Worm.*
By Dr. R. T. LEIPER.

2. *On Epigamic and Aposematic Scents in Rhopalocera.*
By F. A. DIXEY, M.A., M.D.

It is well known that the male of *Ganoris napi*, one of our common white butterflies, exhales a fragrant scent which has been compared to that of lemon verbena, this perfume being probably epigamic in significance. In 1899 and following years the writer detected an odour somewhat similar in character, though not so strong, in the males of certain other British *Rhopalocera* belonging to the sub-families *Pierinæ*, *Satyrinæ*, and *Lycenidæ*. Wood-Mason (1886) had observed similar phenomena in some Indian species, and Longstaff (1903-5) added several other European and Indian forms to the list.

During last year's visit of the British Association to South Africa the writer took the opportunity of extending these observations to native African species, very many of which were found to possess an agreeable odour, suggestive in some cases of aromatic vegetable products, such as chocolate or vanilla, and in others of the scents of various flowers. These also were in every case, with one doubtful exception, confined to the male sex.

In addition to these agreeable perfumes, it has long been recognised that there exists another class of butterfly odours, offensive in character and probably aposematic in function, being more or less shared by both sexes and generally occurring in forms which are on independent grounds believed to be protected. The writer's impressions as to the scents of either sort were in most instances confirmed in the field by Dr. Longstaff.

It might antecedently be expected that both kinds of perfume should in some instances be found co-existing in the same species. Wood-Mason has reported a few such cases from India, and the writer has obtained some evidence that the like condition occurs in Africa.

There is no doubt that the epigamic scents are in most cases distributed by specialised scales (androconia) or 'hairs'; in some forms, however, no special scent-distributing apparatus has been detected. The androconia may be either generally distributed or localised, in the latter case forming the structures known as 'brands,' 'tufts,' and 'chalky patches.' Their action is to some extent under the control of their possessor, the perfume being economised when not needed in courtship. The scent adheres to the scales when removed from the wing, is moderately volatile, and can be extracted with alcohol.

The mode of distribution of the aposematic odours is not so easily determined. They are, as a rule, strongly perceptible even in the uninjured specimen, but are in some instances increased in intensity when the thorax is crushed, and they have at times been found to be attached to the juices which in many species exude from the body under pressure.

The fact that, speaking generally, the agreeable fragrance belongs exclusively to the males, while the repulsive odours are common to the two sexes, sometimes indeed being stronger in the female, seems greatly to favour the interpretation of their function above offered. And if this be the true explanation, it is very remarkable that so much correspondence should exist between human æsthetic preferences and those of some at least of the lower animals.

Specimens of butterflies were exhibited showing (a) forms possessing an epigamic scent, (b) forms aposematically scented, and (c) forms in which both kinds of scent exist independently.

3. *A Remarkable Example of Müllerian Mimicry among African Butterflies.* By Professor E. B. POULTON, F.R.S.

4. *Melanism in Yorkshire Lepidoptera.* By G. T. PORRITT.
See Reports, p. 316.

5. *Report on the Influence of Salt and other Solutions on the Development of the Frog.*—See Reports, p. 327.

6. *Halolimnic Faunas and the Tanganyika Problem.*

(a) By J. E. S. MOORE.

The author dealt, firstly, with the characters of freshwater faunas in general.

It was pointed out how the existing conceptions of the origin of freshwater faunas had arisen. Attention was also drawn to the fact that many freshwater organisms had no near relations in the sea at the present time, this fact leading to the supposition that the freshwater faunas must have been derived from the sea at a somewhat remote period.

The author drew attention to the fact that many freshwater organisms were very widely distributed over the land surfaces of the world. It had been sought to explain this by the conception that such freshwater organisms were capable of great migration.

The difficulties of such a conception were next considered, and a number of other facts in relation to the character of freshwater faunas studied in relation to the probability that the sea is getting saltier in the course of time.

It was pointed out that slow physical changes were capable of producing great changes in animals subjected to them, and the author suggested that this change in the nature of the sea might have been concerned in the production and separation of marine and freshwater faunas.

Whatever the actual cause of the separation, the general freshwater fauna of the globe had features of antiquity about it. It was convenient to regard this general freshwater fauna as the *primary freshwater fauna*.

To this primary fauna it was found that in many places—as, for instance, in the Caspian Sea—there were added numbers of animals which had from their structure obviously been derived from the sea, and were quite independent in origin from the freshwater fauna of the land in which they occurred.

It was to these faunas that he had applied the name of *halolimnic*.

He drew especial attention to the misunderstanding which had arisen through Mr. Edgar Smith's incorrect use of the term *thalassoid*. This term could only be applied to animals which were like, but not related to, marine forms. Halolimnic, on the other hand, meant marine in origin. If a fauna was thalassoid it was not halolimnic, and *vice versa*.

The author congratulated Mr. Cunnington on the many additions he had recently made to our knowledge of the fauna of the great African lakes, pointing out that the present time seemed in every way suited to a renewed discussion of the Tanganyika problem.

Having reviewed the fauna of the lake as we now know it, the author pointed out that the Tanganyika problem consisted of questions as to the nature and origin of the number of animals which were peculiar to that lake.

Regarding this it appeared that only three suppositions could be made:—

1. That the peculiarities in the Tanganyika fauna were due to modifications of the general African freshwater fauna.

2. That these peculiarities were constituted by the presence in the lake of the remains of an extinct freshwater fauna.

3. That they were due to the presence of a halolimnic remnant.

The author inclined to the latter of these suggestions, and pointed out that he attached no great weight to his own former suggestion—that the shells of the Tanganyika gasteropods were possibly similar to those common to the Jurassic seas. The similarity was indeed very striking, but any determination based upon the structure of shells appeared to be extremely doubtful.

(b) *By Professor PAUL PELSENER.*

1. In his attempt to demonstrate the archaic character of these halolimnic molluscs Moore has made use of two quite different methods, seeking, firstly, to show the resemblances between their shells and those of secondary fossils, and, secondly, some resemblances in structure between them and other gasteropods with different shells. The employment of this second method clearly vitiates the first; and justly so, because the external resemblances of shells are often illusory, and the results to which they conduce are therefore quite uncertain. The second method, therefore—the study and comparison of internal organisation—is the only one which can throw light on the question at issue.

2. But even from the latter standpoint I find myself unable to agree with Moore and Digby. In the anatomical studies which they have published on the Mollusca of Lake Tanganyika allusion was made to the affinities of these molluscs with diverse marine forms, *Chytra* having affinities to *Hipponyx* and *Capulus*, *Spekia* to *Lamellaria*, and *Edgaria* (= *Nassopsis*) to the *Architænioglossa*, &c. But there are really no affinities between these forms in the usual sense of the word; and if one examines the resemblances, they are such as are common to all the *Tænioglossa*, to which group the halolimnic genera belong. There is no strict and special resemblance between these and marine forms; and if there be some characters which may be called 'archaic,' other freshwater genera, not 'halolimnic,' such as *Ampullaria* and *Paludina*, present much more archaic characters. I was led to these conclusions in 1886 by a first study of the molluscs of Lake Tanganyika then collected by Captain (now General) Storms.

3. These results are confirmed by the investigations which I have begun upon the new material collected by Dr. Cunningham, and placed in my hands by the Director of the Natural History Museum. I conclude, therefore, that all the 'halolimnic' forms belong to the family Melaniidæ, or to very closely related types. This family presents, in its different parts, a well-known polymorphism of the shell; but along with this there is a great uniformity of organisation, which is also found in the halolimnic genera of Lake Tanganyika. The resemblances of these halolimnic forms to the Melaniidæ are clearly proved by reference to the anatomical characters which are generally used in systematic work—the radula, otocysts, &c.—and by special details of their biology, their freshwater habitat and viviparity—all features in regard to which the two groups present analogies. Digby recognised the melanoid character of the radula of *Limnotrochus*, but among the Tanganyika forms this is certainly the one in which the shell presents the most perfectly marine appearance.

4. The study of two genera, *Giraudia* and *Lavigeria*, the organisation of which was unknown up to the present, also supports the above-mentioned results. Both have multiple otoliths within the otocysts, one otolith being much larger than the others in two species of *Giraudia*. *Lavigeria*, the only genus of which a female has been examined, is viviparous, and possesses a radula which resembles most closely that of the Melaniid genus *Chiara*. The radula of *Giraudia* is clearly similar to that of the Melaniid genus *Ancylotus*. The two species *G. præclara* [Bourguignot] and *G. horei* [Smith] have radulæ so different in structure as to perhaps necessitate their allocation to two distinct genera.

MONDAY, AUGUST 6.

Joint Discussion with Section K on Fertilisation.

The following Papers were read:—

1. *Breeding Experiments in Canaries: an Exception to Mendel's Law.*
By C. L. W. NOORDUIJN.

The experiments carried out by the writer of this paper lead him to regard the results of crossing two varieties or of crossing a variety with a species to be determined, not solely by the nature of the characters united, but also by the length of time through which each of the two characters concerned has existed. According to the strict Mendelian the result of mating a variety with its parent species is the same whether the union takes place in the generation in which the variety arises or a hundred generations later. It is the opinion of the author that, in varieties which have recently arisen, the power of transmitting their own characters is weak, while the tendency to revert is great, when the melo-morphs with which we are dealing are not 'colour' and 'absence of colour,' but two colours.

Two wild canaries caught in Teneriffe were crossed with cinnamons, variegated yellows, and clears. The result of the first of these crosses was like the wild canary in nestling feathers, and up to the first moult. Of the second of the crosses the young were like the wild canary in nestling feathers, but some had white feathers in the tail and wings and a yellow belly.

The offspring of the cross 'wild' × 'yellow' were all variegated yellows, about half of the body being covered with yellow feathers. Now the yellow canary has existed as such for about 350 years; and the inference is that the transmission of yellow, when a yellow is mated with a wild, is due to the length of time for which it has existed.

2. *Preliminary Note on a New Conception of Segregation.*
By A. D. DARBISHIRE, M.A.

3. *The Evolution of the Cock's Comb.* By J. T. CUNNINGHAM, M.A.

The theory of natural selection is a theory of the origin of adaptations or of useful characters. It was originally called a theory of the origin of species, but it has not been proved that specific characters are useful or adaptive. The theory, if true, should be applicable to particular characters; for example, the cock's comb.

This appendage in the wild species is a secondary sexual character; it is of no use to the bird in its ordinary life. It therefore comes under the subordinate theory of sexual selection. It must, therefore, be useful or ornamental in courtship or combat. There is not sufficient evidence to convince us of its importance as an ornament, and in combat it is not only useless, but harmful. This latter proposition is more especially supported by the fact that in the sport of cock-fighting it was the usual practice to 'dub' the birds, i.e., to cut off comb and wattles.

Then the comb and wattles, being a secondary sexual character, are not developed in the females in the wild species, or are very rudimentary in them. The mere preservation or selection of variations would not account for the failure to transmit them to the hen. Similarly, selection does not account for the fact that the comb is not fully developed until the bird is sexually mature. The hypothesis that the comb was an outgrowth, originally due to the laceration of the head in the combats of cocks, would give some reason for the peculiarities mentioned.

A third view of the origin of characters is that they arose fully developed, spontaneously, without selection or influence of external conditions. On this view the phenomenon is not explained. But there is not yet sufficient evidence

of the origin of secondary sexual characters in this way, although such characters, once in existence, certainly vary spontaneously.

The peculiarities of secondary sexual characters, their confinement to one sex and to the period of sexual maturity, and the influence of castration upon them, are the results of a special nexus between them and the sexual organs. Experiment indicates that this nexus is a chemical substance in the blood, produced by the testes. This substance cannot have been the cause of the evolution of the organs, and the existence of the nexus is more in accordance with the theory of external stimulation as the cause than with any other theory.

4. *The Pineal Sense Organs and Associated Structures in Geotria and Sphenodon.* By Professor ARTHUR DENDY, D.Sc., F.L.S.

In the New Zealand lamprey (*Geotria australis*) the pineal sense organs have very much the same structure and relationships as in the European genus *Petromyzon*. The 'pineal eye' is unusually highly developed, and there can be but little doubt that it is a functional sense organ. It lies upon the roof of the thalamencephalon, its upper surface pressed against the wall of the cranium, here represented by connective tissue. Above is a 'plug' of modified connective tissue, above which, again, lie the dermis and epidermis. The complete absence of pigment doubtless allows of the passage of light to the underlying sense organ.

The 'parapineal organ' lies immediately in front of the pineal instead of beneath, as in *Petromyzon*, its upper surface pressed against the fibrous cranium, both structures upon dissection being visible from above. The parapineal lies slightly to the left of the pineal organ, which tends to confirm the view that it represents the left-hand member of an original pair. As in the European lampreys, the parapineal is connected with the left habenular ganglion, while the pineal is provided with a long nerve, passing backwards over the habenular ganglia and connected with the posterior commissure. In the *Petromyzon ammocete* Gaskell holds that the nerve to the pineal eye is connected with the right ganglion, while Studnička seems inclined to think that it is connected with the posterior commissure alone, and therefore that the pineal and parapineal organs were originally unpaired structures. In *Geotria* the pineal nerve is connected with *both* the right ganglion and the posterior commissure, a fact which supports the older view that the largely developed right habenular ganglion represents the 'optic ganglion' of the more perfectly developed right pineal eye.

The histological structure of the pineal agrees in the main with that described by Studnička for *Petromyzon*. The organ consists of a hollow vesicle with an upper, transparent wall (the pellucida) and a lower, deeply pigmented retina, the entire structure being obviously the swollen extremity of the elongated pineal outgrowth, the proximal portion becoming solid and giving rise to the nerve. In addition to the principal cavity there is, as in *Petromyzon*, an atrium, lined by columnar epithelium and embedded in ganglion cells, and in *Geotria* completely separated from the main cavity. The former connection between the two cavities appears to be sometimes indicated by a funnel-shaped depression on the inner concave surface of the retina. The retinal epithelium is composed of sensory and pigment cells, the latter differing from those of *Petromyzon* in that their inner ends are segmented off from the outer by what looks like a limiting membrane, which is very conspicuous in depigmented sections. Careful observation, indeed, shows that both pigment and sense cells are provided with differentiated knob-like inner extremities, those of the latter projecting into the cavity of the eye further than those of the former. The cavity of the pineal eye is occupied by a network of fibres, connected both with irregular projections of the pellucida and with the knobs of the sense cells.

Reissner's fibre, lately fully investigated by Sargent, is very conspicuous in *Geotria*, where it can easily be traced from the central canal of the spinal cord, through the fourth ventricle and *iter*, to the neighbourhood of the posterior commissure, beneath which it breaks up into fibrils, which are almost certainly con-

nected with the epithelium of the ependymal groove, as described by Sargent for *Petromyzon*. It is easy to trace some of the fibres of the pineal nerve to the inner side of the same epithelium, through which they are possibly connected with Reissner's fibre.

My observations in the case of *Sphenodon* are as yet incomplete, but certain remarkable and hitherto unrecorded features have come to light. As in *Geotria* and *Petromyzon*, the sense cells have the form of unpigmented rods, whose slender apices project into the cavity of the eye, and are there connected with a network of fibres, but without being appreciably enlarged. Between the sense cells lie irregular elongated masses of dark-brown pigment granules, no pigment cells having been yet recognised. Behind the layer of pigment and sense cells lies a layer of nerve fibrils and ganglion cells, backed by another layer of doubtful significance. The lens is almost completely disconnected from the retina. Histologically it exhibits great peculiarities, the most remarkable of which is the presence of a large 'central cell,' irregular in shape, with a conspicuous nucleus, and looking like a large ganglion cell.

5. *The Birds and Mammals of Yorkshire.* By OXLEY GRABHAM.

TUESDAY, AUGUST 7.

The following Papers were read:—

1. *Spicule Formation.* By Professor E. A. MINCHIN, M.A.

A spicule is to be defined as a sclerite of intra-cellular origin and growth. It may be formed of organic material entirely (example, acanthin spicules of Radiolaria), or the organic material may become impregnated with, or even entirely replaced by, mineral salts. The interest attaching to the study of spicules lies in the fact that an inorganic body is thus formed in the midst of the living substance, and that the material composing the spicule may be subject to physical laws or exhibit peculiar properties arising from its inherent molecular constitution. Thus in calcareous sponges each spicule, whatever its form, is always a single crystal of calcite, but the form of the spicule is always quite different from that which the calcite crystal normally assumes when formed in non-living surroundings, so that the crystalline nature of the spicule could not be suspected from simple inspection. Hence spicules represent a meeting-ground of organic and inorganic forces. What part is played by each of these factors in determining the form of the spicule? Do the vital activities alone assert their sway, or are the inorganic forces able to modify the joint product?

In calcareous sponges only three forms of spicule are found (i) *Monaxon*, simple needle-like forms with one end embedded in the tissues, and the other projecting into the water; (ii) *Triradiate*, i.e., three rays joined at a centre, and completely embedded in the sponge wall; (iii) *Quadriradiate*, i.e., triradiate, with a fourth ray joined to the other three at or near the centre and projecting into the interior of the sponge. There are, further, two distinct types of triradiates, characterising different sections or families of the Calcareae—(1) equiangular, in which the three rays meet at equal angles of 120° ; (2) sagittal, in which there is always an unpaired angle greater than 120° and two paired angles less than 120° .

Primary spicules, derived each from a single mother-cell, must be distinguished from secondary spicules or spicular systems, derived from more than one mother-cell. In *Leucosolenia* each monaxon is a primary spicule, whereas the triradiates are secondary, each ray being formed in the same way as a monaxon. Each triradiate is thus to be interpreted as a system of three primary spicules joined together. In the quadriradiate, the fourth ray, from its formation, is to be regarded as a primary spicule fused to the triradiate system.

It does not seem possible to bring the forms of the monaxons into any relation with the crystalline nature of the material composing them, but, on the other hand, all their peculiarities can be correlated with their position and functions in the sponge body. Unlike a crystal, the monaxons have dissimilar ends, which can be attributed to the fact that one end is embedded in the body-wall, while the other projects into the water. The monaxons are invariably curved so as to project outwards more vertically from the body-wall, and the free end is frequently barbed; they are thus rendered more efficient as protective organs. Such characters cannot be explained on any physical or mechanical ground. Hence, as regards the primary spicules, we may agree with Maas that they are the outcome of two distinct activities—an organic-cellular, determining the form of the spicule, and an inorganic-crystalline, determining only the material.

In the triradiates, similarly, the rays may be straight or curved in various ways; and here again it is not apparent how the form of the individual rays can be related with the crystalline structure. On the other hand, with regard to the angles at which the rays meet, it is a remarkable fact that in one section of these sponges the triradiates are unfailingly equiangular. The principal rays may have, normally or abnormally, secondary branches on them, which are also set at an angle of 120° with one another or with the main stem. That this regularity is due to an inherent hereditary tendency on the part of the sponge to fix one ray to another at an angle of 120° is negatived by the fact that the rays of the triradiates often meet irregularly in the early stages of growth, but become symmetrical as growth proceeds. Maas's observation that sponges grown in sea water devoid of CaCO_3 produce organic sclerites with no trace of calcite, appears to show that hereditary tendencies influence the formation of spicules to the extent of producing combinations of three primary monaxons to form a triradial system; but I do not gather that the organic sclerites have the regular symmetry of angles. I am forced to the conclusion that here the physical properties of the material play a part in determining the spicular form.

In the majority of *Calcarea* there occur sagittal triradiates which approach the T-shape. Here we come upon a remarkable fact, discovered by Mr. Bidder. He found that in equiangular triradiates the optic axis of the crystal is always at right angles to the plane of the rays, but that in the sagittal triradiates the optic axis is always inclined to the plane of the rays in such a way that, if viewed along the crystalline optic axis, the spicule would always appear equiangular in the projection, whatever its actual shape might be. Hence the relation of the angles at the junction of the rays to the optic axis is the same in all cases, and deviations from the primitive equiangular condition can only be brought about by tilting the optic axis.

The conclusion to which I have come is that in primary spicules the form is in no way dependent upon the physical properties of the material, but is regulated solely by biological conditions; where, however, primary spicules are joined to form spicular systems, physical properties may exert an influence on the form of the spicule as a whole by determining the angles at which the rays join. This agrees with the results I arrived at with regard to the spicules in the *Hexactinellida* ('Zool. Anzeiger,' 1905).

2. *Suggestions for a more Systematic Study of Oceanic Plankton.*

By G. HERBERT FOWLER, B.A., Ph.D.

In opening the discussion on plankton the writer sketched the history of its study, with special reference to Hensen's theories on the subject. The modern subdivisions of the plankton and their composition were outlined, and attention drawn to the two schools of plankton-students of the present day—the one almost physiological, the other more purely zoological. The methods of the former were regarded as far more refined than those of the latter. A number of interesting problems which demand attention on the zoological side were briefly

indicated, and for their solution it was suggested that oceanic expeditions should be confined to the systematic study of small areas instead of making long voyages; that the upper zones of water should be investigated more minutely and with more care than has hitherto been the case; that standard tow-nets should be adopted internationally by all expeditions in order to afford means of comparison of the fauna in different seas and under different conditions; and that facts are more worthy objects of collection than museum specimens of new species.

3. *Sterile Eggs of Purpura.* By PROFESSOR PAUL PELSENER.

4. *Traces of a Periodic Law in Organic Evolution.*
By HENRY M. BERNARD, M.A.

The 'cell' has hitherto been the only recognised unit of structure for the analysis of the forms of life, and our conception of the evolutionary story has never advanced beyond that of a vast multitude of cell-masses streaming through time, slowly but perpetually changing their shapes, as a rule, from the simple to the more complex, and in this respect diverging from one another in all directions. In this stream, here and there, definite form-sequences can be recognised, but we have to confess that during the last fifty years little has been done beyond accumulating fragmentary evidence for the truth of the general doctrine. Hardly anything of importance towards the unravelling of its underlying laws has been added, and signs of weariness are betrayed in its further discussion.

The idea embodied in this paper was arrived at from two points of view:—

(1) Work on the stony corals suggested that the cell has not been the only unit of structure. A normal coral stock, *i.e.*, a stock not too highly specialised, may be the product of at least *three units*: (*a*) the cells which, by division, build up the polyp; (*b*) the polyps which, by a modification of division (fission or budding), produce a colony; (*c*) the colonies which, by what may be a further modification of division, produce a stock.¹

This suggestion that the larger forms of life may be built up of several units of structure, such as the *cell* and *others of grades above the cell*, is supported by what we know, *e.g.*, of the important place the annelids (themselves built up of series of segments) hold in animal morphology, and also by the fact that in the vegetable kingdom repetition of parts seems to be the almost invariable rule for the building-up of the larger forms—that is, of parts which are themselves complicated structures, and also possibly analysable by other (*i.e.*, higher) units than the cell. These suggestions call for a fresh survey of the whole evolutionary series from this point of view—that is, in order to see whether the forms of life do not reveal other units of structure above the cell; and if above, why not also below?

(2) The other line along which the subject was approached was a long comparative analysis of animal tissues in order to ascertain what support they give to the author's description of the essential structure of the 'cell layers' of the vertebrate retina.² This analysis and its results, which are being put into book form, have also, during the difficult process of setting them out *in extenso*, revealed a succession of structural units of increasing complexity, *the cell being only one in the series.*

Traces of a law of successive units of increasing complexity have thus been reached along two quite distinct lines of research. In neither case was it a sudden happy inspiration or mere speculation; in both it was a conclusion slowly forced

¹ This point is worked out in further detail in vol. vi. of the *British Museum Madreporaria*, now in the press.

² See Retinal Studies, Part VI., *Quarterly Journal of Microscopic Science*, vol. 47, pp. 303–362, pls. 27–29.

on the mind after years of working at the facts. During the second line of work the possibility was further perceived (1) of defining what constituted a unit of organic structure; (2) of showing that the progress from unit to unit could be described in a formula, this being in each case essentially the same, and differing only in the increased complexity of the factors.

Given, then, (1) the discovery of four or five units of animal structure, all *alike* in so far as they show certain definite characteristics which make them capable of acting as units of structure; and (2) the fact that the morphological transformations by which the units are successively evolved out of those which go before follow essentially the same course in each case, the inevitable conclusion is that a *periodic law* underlies the evolution of organic life.

So far the author believes that five consecutive units in the animal series, with a considerable number of the connecting links, are distinctly recognisable among existing forms, and, further, that it will be found to follow, as a natural inference from these five (natural because the processes can be formulated—and there is no reason to believe that a formula which is true for the five should be suddenly broken) that at least one lower and one higher unit can be sketched in outline.

Quite apart from the theoretical interest attached to the fact of periodicity and all that it now means, and may in the future mean, comes the interest in the actual details, such as, for instance, the possibility afforded of assigning to groups of both animal and vegetable organisms, which have hitherto been difficult to account for, places of origin from this or that 'period.'

Lastly, the author, being a zoologist, has naturally confined himself to the animal series; but the animal and vegetable series are found to meet at a point which it seems now possible more clearly to define, and one of the objects of reading this paper now, rather than waiting a year or so till the book is published, is to appeal to the botanists for their evidence for or against what appears to be a new evolutionary law.

5. *On the Relation of Scientific Marine Investigations to Practical Fishery Problems.* By Dr. E. J. ALLEN.

6. *The International Investigation of the North Sea Fisheries.*
By Dr. W. GARSTANG.

WEDNESDAY, AUGUST 8.

The following Papers were read:—

1. *Notes on the Habits of Galatheidæ.*
By Miss E. F. GALLOWAY and HERBERT J. FLEURE.

The numerous moults and the tough coats of most of the Decapod Crustacea are disadvantages for animals of swimming habit, and in many members of this group the habit is a waning one. The shore forms of *Galatheidæ* may be described as descendants from swimming ancestors adapted to a life clinging to the undersides of boulders.

Galathea squamifera may progress by flapping the permanently bent abdomen, it may lurk in holes with chelipeds outstretched for prey, it may walk in almost crab-like fashion, or it may, and most often does, cling to the lower surface of a large boulder. When clinging, the walking legs are spread out as radial grapplers, the centre of the ellipse being the longitudinally concentrated ventral thoracic ganglia. The walking legs have lost their chelæ, and to a great extent their cleaning function, and end in grappling-hooks; but the last thoracic limb, though

small and thin, is an efficient cleaner of the limb-bases and of the branchial cavity.

Clinging has led to natural selection of a relatively short body, while breadth has increased. This has gone so far in *Porcellana* that the grappling legs are there the radii of a circle rather than of an ellipse. In *P. platycheles*, more especially, the legs are almost regularly disposed around the circle, and each has the shape of the arc of a circle, securing firmness of attachment without excessive rigidity. Broadening of the body has given increased breadth to the branchial cavity, and with broadening has gone a flattening down of the carapace, reducing the danger from side blows. The result of this is that the long axes of the gills are sloping in *Galathea* and nearly horizontal in *Porcellana*; the chinks between their component leaflets are therefore almost vertical, and thus less likely to harbour foreign particles than the horizontal chinks between the gill leaflets of a *Penæus*. The branchiostegite, with its inbent edge, protects the branchial chamber of *Galathea* better than the same structure does that of *Penæus*. This chamber is still better protected by carapace and leg-bases in *Porcellana*, and, with the Galatheid cleaning limb in addition, there cannot be such need of epipodites, at any rate for protection and cleaning, as in the *Penæidæ*. In addition to the plate of the first maxillipeds, we find epipodites in both *Galathea* and *Porcellana* on the third maxillipeds, the chelipeds and the first two walking legs; they are, however, reduced, and more so, especially the posterior ones, in *Porcellana* than in *Galathea*.

The chelipeds of *Galathea* and *P. longicornis* transfer food to the mouth, and in the latter also assist locomotion, being pressed against a surface irregularity and then partly straightened, with the result that the body is pushed backwards. *P. platycheles* is too completely flattened for the chelipeds to bend easily in towards the mouth region; but if food is once secured in the cavity between and beneath them, it is likely to be swept into the mouth by the maxillipeds, while the thick row of long hairs stretching down from the outer edges of the chelipeds must help to stop all but very small particles. In *Macrura* and *Galathea* the respiratory stream enters between the leg-bases, especially the posterior ones; but in *Porcellana*, *P. platycheles* more especially, the entrance channel is almost restricted to the gap just behind the chelipeds. Here the general hairiness of the species is specially marked, and one or other of the walking legs is brought close up against the cheliped, so the channel is narrow and barred by an efficient straining apparatus. The highly developed protective arrangements for the branchial cavity allow *P. platycheles* to thrive where neither *Galathea* nor *P. longicornis* could survive, and partly account for the greater tenacity of life of the first named.

The antennules are important water-testers, and are periodically cleaned by the hair-comb on the inner side of the third maxillipeds. The flicking of the antennules and sweeping of the maxillipeds seem to create a current forwards, which might bring grit against the sensory hairs. The teeth and notches of the rostrum of *Galathea* localise that current in the forward notch on either side, and this notch differs from the others in possessing a thick row of hairs for straining. *P. longicornis* has the rostrum reduced, but a row of upright hairs on either side, a little way behind the front edge of the carapace, perform the straining function. These hairs are not as conspicuous in *P. platycheles*, but the general hairiness must here hinder the passage of minute fragments over the carapace-edge. The third maxillipeds, further, brush the front of the carapace.

Every moderately active clinging animal may fall, and must have a method of righting itself. *Galathea* needs this less, for, even when reversed, it can progress by flapping the abdomen till it comes beneath a stone to which it can cling. Sometimes, however, it grips usually with the third pair of walking legs on either side, and by contracting their muscles and flapping the abdomen at the same time it is able to turn over, using the back edge of the body as an axis.

In *Porcellana*, straightening of the third walking legs raises the body, and the flapping of the abdomen is then just sufficient to jerk the back of the carapace backwards till the vertical position is reached and passed and the animal has turned over. The great claws are meanwhile brought backwards to diminish the moment opposing the righting movement. *P. platycheles* is more light-shy than

P. longicornis, and the working of legs and abdomen for righting is much better coordinated; this enables us to understand the facts, noticed by Milne Edwards and Bouvier, that *P. longicornis* has a long chain of abdominal ganglia, but that these are gathered up into the thorax and more concentrated in *P. platycheles*.

2. *Some Notes on the Mammalian Mandible.*
By Professor RICHARD JOHN ANDERSON, M.D.

The size and shape of the mandible in Mammalia seem to depend mainly on:—

1. The size of the angle between the basioccipital and spinal axis.
2. The size and character of the teeth.
3. The nature of the muscle attachments.
4. The extent and kind of the movements.
5. The conditions of the parts beneath and in its neighbourhood.

3. *A Note on the Manus of the Dolphin.*
By Professor RICHARD JOHN ANDERSON, M.D.

The number of phalanges, which seems to vary, is made up of the normal phalanges, which have each one or two epiphyses and pseudo-phalanges which owe their existence to a deposit of osseous matter beyond the normal phalanges. This deposit is probably due to the length of the flipper and the thickness of its tissue, and the subdivisions probably bear some relation to the tenuity.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION—Right Hon. Sir GEORGE TAUBMAN GOLDIE, K.C.M.G., D.C.L., F.R.S.

THURSDAY, AUGUST 2.

The President delivered the following Address :—

It is just a quarter of a century since the British Association held its last meeting in this ancient city of York and celebrated the Jubilee of its foundation, so that from the moment of accepting the invitation to preside over this Section it was clear to my mind that the most appropriate subject for my Address would be the progress of geography between that Jubilee and what I believe would be called in other spheres our Diamond Jubilee. For although the immediate concern of geographers is with the earth's surface, yet we cannot avoid sharing with the rest of our race the religious observance of astronomical periods and the tendency to regard certain numbers of such periods as having a peculiar value. Geographers, indeed, might be excused some tendency to this human weakness, as they are entirely dependent on astronomical methods and on an elaborate use of numbers for the primary necessity of ascertaining where they are on that surface which it is their business to examine and describe.

I do not propose in this Address to deal only, or even chiefly, with the progress of exploration since our Jubilee Meeting in York, for although that progress has been remarkable, its effects are probably less far-reaching than the growth during the same period of the scientific treatment of geography; while both of these advances, taken together, are, to my mind, of less importance to our country—and we are, after all, a “British” Association—than the spread of the geographical spirit amongst our people, on the main cause of which I shall say a few words. Let me deal, then, with these matters in turn, bearing in mind, however, that the two latter subjects—the growth of scientific method and what I may term the democratisation of geography—are so interwoven as to make it impossible to separate them altogether.

First, then, as to the advance of exploration since 1881. In that section of the Arctic regions in which the Nares and the Greely expeditions had done their work considerable progress has been made, mainly by Lieutenant Peary, who carried the investigation of the coast of Greenland further north and east than had been the case before, while his contributions to our knowledge of the inland ice are of much value. The explorations of Captain Sverdrup among the lands lying north of America, and the not less important expeditions of Nordenskjöld and Nansen across the centre of Greenland, have added much to our knowledge, not only of the physical geography, but also of the geology, biology, and ice conditions of a land which, though lying to a large extent outside the Arctic circle, is essentially Arctic in character. Another expedition, under Captain Amundsen, is now completing its work, which has extended over about three years, around the North Magnetic Pole. Both English and Swedish expeditions have greatly improved our knowledge of the islands of Spitzbergen, while Jackson, Nansen,

and others have enabled us to lay down with something approaching to accuracy the archipelago of Franz-Josef Land. But perhaps the largest addition to our information about the North Polar region during these twenty-five years has been through the ever-memorable expedition of Dr. Nansen, during which he reached within four degrees of the Pole, obtained soundings down to two thousand fathoms, and collected a vast amount of meteorological, physical, and biological information, which has enabled him to work out, to a large extent, the probable conditions which prevail around the Pole itself.

Let us pass now to the other end of the earth—to the great continent which, as now appears beyond doubt, surrounds the Southern Pole. Here also very considerable progress has been made during the last twenty-five years. For a long period after the time of Ross, over sixty years ago, only spasmodic efforts had been made to continue the work of South Polar exploration. But in recent years numerous national expeditions—Belgian, German, Swedish, and British—have pursued this work, producing a mass of data in geology, physics, meteorology, and biology which should throw a flood of light both on the present conditions and on the history of this dead continent. Perhaps, as the successor in the Presidential Chair of the Royal Geographical Society to that great geographer, Sir Clements Markham, a Yorkshireman, I may be allowed to dwell specially on the splendid and varied work of the National Antarctic Expedition under Captain Scott, which not only carried our knowledge of the Antarctic continent about five degrees further south than the limits of exploration previously reached, but also collected a vast amount of scientific information.

And now, leaving the Polar regions, let me try to recall the position of exploration of the African continent in 1881. Stanley had only recently completed that history-making journey across Africa, by which he traced on the map the last great line in the framework of the continent, the river Congo; and so accurate were his observations that, notwithstanding the vast number of later explorers, the course of the river laid down by him has practically remained unaltered. But a glance at a map of Africa of 1881 reminds us that enormous blanks existed, almost from the tropic of Capricorn to the upper bend of the Niger, in the centre and west of the continent; that the region between the equator and the Gulf of Aden was almost unknown; that our knowledge of the great lake region of Central Africa, as also of the eastern and western tributaries of the Upper Nile, was most imperfect. Little had been done for the Central Sudan States since the days of Barth, and only very vague notions existed as to the real character of the Sahara. Since 1881, through the efforts of Stanley himself and of a host of Belgian, French, and British explorers, the map of the whole Congo Basin has been crowded with rivers, defined with a fair approach to accuracy, while the hypothetical lakes of the past have evaporated. In the southern quarter of the continent, all the region from the northern limit of Cape Colony up to the Congo watershed and Lake Tanganyika has been to a large extent mapped in a provisional way and all the main features laid down. The work of exploration in the eastern regions of Africa has been no less complete. Stanley, on his expedition for the relief of Emin Pasha, discovered the important range of Ruwenzori, and laid down with some precision the outlines of Lake Albert Edward; while British and German explorers have made very fully known those remote feeders of the Nile which supply the Victoria Nyanza, and have contributed largely to our knowledge of the great Rift valleys and the lakes which occupy them. Joseph Thomson, the original pioneer from the East Coast through Masailand towards Uganda, has been followed by many others, so that the map of all this region is thickly studded with new features; while the Anglo-German Boundary Surveys have been able to lay down a trigonometrical basis for a complete and trustworthy map of the whole region. Somaliland, the outlying parts of Abyssinia, Lake Rudolf, the rivers that run into it, and the rivers that run from the south-east into the Sobat and the Nile—all these have been explored and laid down with wonderful fulness since the Association last met in York; while, after the breaking down of the barrier of Mahdism, the advance in our knowledge of the Egyptian Sudan became almost too rapid for record. Nor has the progress of exploration in Western Africa been

less remarkable. Through the energy of the officials of the Chartered Royal Niger Company, of Sir Frederick Lugard and his staff, of Binger, Monteil, and a host of other French as well as German explorers, great blanks have been filled in, and mapping of the most detailed character in many districts has been rendered possible. Our knowledge of Lake Chad and of its present and its probable past has been greatly extended, and many problems have been suggested which will provide ample work for the geographer and the geologist. The Sahara has been crossed and recrossed in many directions during recent years, especially by French explorers, with the result that we have been compelled to revise the prevailing impression of the great desert, which is by no means the featureless waste which it used to be considered. Taking the continent of Africa as a whole, its map has been thickly covered with a network of features, and, so far as cartography is concerned, all that remains to be done is to fill in the meshes of that network with local details and to give precision to our maps by careful triangulation.

I have dealt at some length with exploratory work in Africa, because it is the continent of which we knew least in 1881, and our knowledge of which has made the greatest strides since then; but the contemporaneous advance of our acquaintance with the topographical and physical conditions of other portions of the lithosphere has been very remarkable. A host of explorers, of whom I will only mention Younghusband, Littledale, Bower, Sven Hedin, and Huntington, have mentioned the centre of Asia in various directions. During the same period the topographical survey of India has been brought to completion, while Indian officers and others have carried geographical investigations far beyond the limits of our great Dependency, and have made much progress in the mapping of Baluchistan and Persia. The recent Tibet expedition practically settled the question of the sources of the Brahmaputra, and laid down its central and upper course. I do not know whether we should regret that they were not able to fill in the long gap in the lower course of that river, for we still enjoy the pleasures of hope of solving this interesting problem, which, with some equally unsolved problems in other parts of the globe, reminds us that explorers need not yet sigh, like Alexander, for other worlds to conquer. Numerous travellers have crossed China in all directions, and have done much for its accurate mapping, as have also the French in their Indo-Chinese possessions. Even in Turkey in Asia, where serious difficulties are encountered by explorers, such men as Ramsay and Maunsell have done much valuable work.

Turning to America, the very efficient surveys of Canada and of the United States have made an immense advance in the accurate mapping of their respective countries, while much has also been done in Mexico and in Central America. The Argentine Republic and Chile have made great progress in the exploration and mapping of their territories, and Peru and Bolivia have within recent years shown creditable diligence in this respect; but there remain in the southern continent areas covering from two to three million square miles still practically unexplored, so that to-day, as far as preliminary exploration is concerned, there is more to be done in South America than in Africa.

I have, perhaps, sufficiently indicated the marvellous progress of exploration of the lithosphere. I have naturally less to say of the advance of oceanography, for the 'Challenger' expedition had completed its voyages before the Jubilee meeting of the Association in 1881, although the results were not then worked out. It is, indeed, only within the last few years that Sir John Murray has been able to complete this immense work, which occupies no less than fifty volumes. Since the voyages of the 'Challenger' there has been no equally extensive expedition for oceanographic work, but the study of the oceans has been carried on steadily, if slowly. The German expedition in the 'Valdivia' added much to what the 'Challenger' had achieved, especially in the Indian Ocean; where also, only within the last year, Mr. Stanley Gardiner has carried out an enterprise which promises to yield results of the first importance. Further east, in the seas around the Malay Archipelago, the Dutch 'Siboga' expedition added something to our knowledge of the ocean bed; and not less important than any of these later expeditions was the enterprise carried out over a series of years in the Pacific and in

the Gulf of Mexico by Mr. Alexander Agassiz, entirely at his own expense. The cable-laying companies have also done a good deal on behalf of oceanography, and some of the results of their investigations have been published by the Royal Geographical Society, under the superintendence of Sir John Murray. The immensely valuable work constantly carried on by His Majesty's surveying vessels, under the direction of the Hydrographic Department of the Admiralty, is so generally known as to make it unnecessary for me to dwell upon it.

Long before the close of the nineteenth century, however, oceanic navigation had ceased to be of a pioneer or exploratory character, except in the Polar regions, and had devoted itself to the no less important tasks of filling in details and of undertaking scientific research, while the comparatively new subject of limnology, which deals with those other portions of the hydrosphere known as lakes or inland seas, and which has had such immense and valuable labour devoted to it in this country by Sir John Murray, falls strictly within the limits of scientific research. To this end all geographical travel and all geographical study must come; and I am thus led to the second branch of my address, dealing with the growth of the scientific side of our subject and the concurrent spread of interest in its study. On these points I propose to deal mainly with our own country; but I shall be compelled to draw certain comparisons, however unwillingly, with the more advanced conditions, in this respect, of other countries, and notably of Germany. No one, indeed, could assert that the importance of problems relating to the geomorphology of the lithosphere, to the distribution of land and water, and to the influence of these (combined with climatic conditions) upon the distribution of life and on human interests, were not recognised amongst us long before the last meeting of the British Association at York. The underlying principles of scientific geography have been perceived in all ages and in all countries by a few thinkers; but so late as twenty-five years ago a true conception of the functions and scope of geography was confined to a very limited circle of specialists. In confirmation of this, I may remind you of an inquiry which the Royal Geographical Society undertook about that time into the position of geography at home and abroad.

For many years previously the Society had been endeavouring to awaken the public mind as to the high capabilities of geography when dealt with on scientific lines, and to encourage the teaching of the subject on a higher plane by the award of medals on the results of examinations. The failure of these attempts induced the Society to make the investigation to which I refer, and its report (published only a few years after the York meeting) may be regarded as the starting-point of the revolution that has since occurred. It was found that Germany even then had professors of geography in nearly all its universities, and a number of thoroughly trained and earnest students who devoted themselves to investigation of the subject in all directions; and that in Austria, as well as in Germany, geography had attained a position, both in universities and in schools of all grades, practically on a level with other subjects of education; while in this country it was generally regarded with apathy, and even contempt. It had no place in our universities; it was barely tolerated in our secondary and higher schools; while in the simple geography of our elementary schools there was great room for improvement. Practical work in geographical research scarcely existed, except in so far as it was an outcome of geology. There was no encouragement for students, there was no high-class geographical literature, such as existed in Germany, and for standard works we had to resort either to that country or France. The great treasure-house for geographers was Elisée Reclus's '*Géographie Universelle*,' which, fortunately, was translated into English. There existed, indeed, a few popular works in this country, but these were more or less of a purely descriptive and unscientific character, excluding altogether the fundamental data of the subject. In the Society's report to which I have referred were also given very interesting quotations from the opinions of headmasters of English public schools as to the value of geography and the educational position which it ought to have. It was melancholy reading. Only a few of them took a favourable view of the subject, while the majority treated it with little respect. The remarks

of those who favoured its study are to-day chiefly interesting as showing the entire inadequacy of the methods of geographical tuition in those days and the little importance attached to it in educational circles. I must, however, quote with approbation the words of one master, who said: 'I feel strongly the great importance of the subject, not only as a mental discipline, an essential part of a liberal education, but as more especially necessary for Englishmen, many of whom will be called upon in after-life to turn their geographical knowledge to practical and serious account'; and he added: 'One of the difficulties in doing justice to the claims of the subject is the somewhat absurd prejudice in teaching geography, as if it were less worthy of first-rate men than Latin prose, or essay writing, or criticism.' On the other hand, most of the headmasters threw cold water on any attempt to give geography a substantial place in our great public schools. They considered it not sufficiently important as an educational instrument; it was hardly a discipline; it was little more than an effort of memory; it was quite worthless educationally till it became a branch of history; problems in it could not be set. These masters were supported by the opinion of a distinguished geologist that geography was not suitable as a university subject because it was a 'graphy,' and not a 'logy.' Nor, indeed, can it be contended that these depreciatory views of geography, as it was then generally taught, were unreasonable. The text-books of that time were, as a whole, worthy of the position which the subject held in the education of the country, and on a par with its reputation among the educated public. The use of maps in the daily newspapers was almost unknown; while as regards military geography, the late Lord Napier of Magdala, at the opening of the Education Exhibition of the Society, forcibly contrasted the position at home with the importance attached to the subject in the German Army, where at the manœuvres every third soldier has a map of the ground, and where in the Franco-German war maps formed part of the equipment of every company. If the position of geography in this country was so unsatisfactory a quarter of a century ago, it was not because its raw material was wanting in our language. On the contrary, few countries then possessed a literature of travel and exploration so wide and of so high a class as ours. The source of our weakness was the paucity of men qualified to apply scientific method to this raw material, and there was no institution where it was possible to obtain a thorough training in geography, such as could be obtained at a score of universities in Germany, Austria, and France. This was the position which had to be faced before placing the subject on a more satisfactory footing.

It is unnecessary for me to describe in detail the methods adopted by the Royal Geographical Society—so far as its resources and influence permitted—in carrying out the work of reformation. I need only bring before you the general results. No one will now doubt that the active minds in this great movement were right in believing that the surest means of influencing our schools of all grades, and also of obtaining in the country generally a recognition of the subject as a department of science, as a field for research, and as a subject of practical importance in various spheres of national activity, was to obtain, in the first place, proper recognition at our great universities. Attempts had, indeed, been made in the same direction as far back as 1871 and 1874, but without effect. I need hardly remind you that the later efforts of the Society had a very different result. For many years now there has been a school of geography at Oxford, while a readership established at Cambridge several years ago has also developed into a fairly well-equipped school. At Oxford there is a reader with a staff of three lecturers, and a diploma in geography is granted which practically amounts to honours in the subject. The field covered may be seen from the subjects of examination for this diploma. They are: (1) Regional Geography, (2) Climatology and Oceanography, (3) Geomorphology, (4) Ancient Historical Geography, (5) Modern Historical Geography, (6) History of Geography, and (7) Surveying. It may give a more complete idea of what English students regard as included in their subject if I mention the principal topics in the examination on regional geography—the cartographical analysis of the physical regions of the world—an elementary knowledge of the chief generalisations regarding the surface forms of

the land; the movements of air and water, and the distribution of plant associations, animals, and man; the chief facts of modern political and economic geography, considered in relation to the influence of physical features. Candidates are also required to be familiar with the principles of map-making by plane table, prismatic compass, and clinometer, with the representation of relief, and with the orientation, reading, and measurement of maps. Equally thorough and exhaustive are the various topics included under the other heads of examination. Both in ancient and modern historical geography the subject has to be considered in relation to the influence of physical features. The standard adopted at Oxford is as high as that which exists at any university in Germany. The establishment of a school at Cambridge being recent, one cannot yet speak as positively of its success as in the case of Oxford. But Cambridge has gone a step further than Oxford in placing geography as a subject in the examination for its B.A. degree; and while that may be regarded as a simple pass, the student may also enter for the examination for the diploma in geography, the standard of which is no less high than that at Oxford, while the ground covered is essentially the same. In both universities the training in cartography and surveying is thorough, and it is to be hoped that such students as propose to follow either a military or a colonial career will take advantage of the opportunity thus presented. The example of Oxford and Cambridge has been followed elsewhere, though to a lesser extent. In the University of London there is a board of geographical studies, and the subject holds a substantial place in the University examination, and is a compulsory subject for a degree in economics. There are chairs or lectureships of geography at Victoria University, Manchester, at the University of Liverpool, and at the University of Birmingham. Steps are being taken to establish a chair at the University of Edinburgh; while other institutions of a similar kind would be glad to follow the example of the great universities if only their funds permitted. In the elementary schools the programme is nearly all that can be desired, the one thing needed here, as elsewhere, being a sufficiency of teachers who have been thoroughly trained in the subject. In the secondary schools progress has been somewhat more slow; but there has been a steady advance in recent years, and a step recently taken by the Board of Education, in issuing a very satisfactory syllabus for the teaching of geography, is certain to give a strong impetus to the subject. In the London School of Economics, under the directorship of Mr. Mackinder, which is attended annually by over a thousand students, geographical teaching holds a place of the first rank. The publishers have kept pace with this great revolution in the schools, so that to-day there is no difficulty whatever for anyone, from the elementary school up to the university, in obtaining a text-book, or an atlas, or special maps suitable for his requirements. The country has been, indeed, almost flooded with cheap atlases issued in parts, some of them of a highly creditable quality, while the slides of photographs taken by explorers are sold by the thousand for educational and lecture purposes.

The main cause of this remarkable growth of interest in geography amongst our educated classes dates back to about three years after the last Meeting of the Association at York. In 1884, Germany, which in the middle of the century had been still said to rule the air (while France ruled the land and Britain the sea), and which in later years had been absorbed in the process of unification by blood and iron, suddenly launched out as a world Power and gave the signal for the partition of Africa. England and France, in both of which countries a few men had been carefully preparing, during several years, for this inevitable partition, hastened to join in the international race, and the spirit of colonial expansion, long dormant, reawakened, and reached out to all parts of the earth where settled government did not forbid advance. We, who have lived through the last quarter of a century, are apt to underestimate the revolution through which we have passed, for a true analogy to which we must go back to the Elizabethan age. The impulse given by this movement to the study of geography can hardly be overestimated. War has been called the best teacher of geography, and certainly Napoleon, the highest exponent of the art of war, was as ardent a student of geography as he was of mathematics; but it now appears that empire-building is an even

greater factor than war in advancing and popularising geographical knowledge. Amongst the educated classes of England, France, and Germany, and, in a lesser degree, of Italy and Belgium, there are few persons who have not had relatives or friends engaged as explorers, or missionaries, or officials, or soldiers, or traders in previously little known parts of the world, while countless numbers have been concerned in the new movement through vast shipping and other interests that shared in it. The Press, which prior to 1884 had paid little attention to the outlying lands in question, gradually devoted more and more space to everything connected with them, and continually produced most useful maps, showing not only their physical features, but also their economical conditions. It is not my business here to attempt to forecast the judgment of the future historian on the more general results of this colonial expansion, but he will assuredly recognise its enormous effect on popular attention to geographical subjects, as well as, or even more than, on exploration.

It must not be inferred that the popularity of a subject is taken by me as a test of its place in the ranks of science; but, owing to the widening of the area from which students can be drawn and men of genius evolved, this democratisation of geographical ideas is, to my mind, a very hopeful feature as regards the future of the scientific treatment of the subject.

I should have to extend my address to undue length if I attempted to demonstrate the recent growth of the scientific method at home by giving you even an imperfect catalogue of the geographical books and papers of a scientific nature published during the period under consideration, and especially in later years. I can only select for mention a few typical books, such as Dr. Mill's 'International Geography,' Mr. Mackinder's 'Britain and the British Seas,' Mr. Hogarth's 'Nearer East,' and Sir Thomas Holdich's work on 'India,' and other works in Mr. Mackinder's series entitled 'The Regions of the World.' As to papers dealing with this kind of work, I will mention those by Messrs. Buckman and Strahan giving the results of their investigations on the river systems of the west of England; by Mr. Cooper Read on the river system of East Yorkshire; by Dr. Herbertson on the major natural regions of the world, and on the distribution of rainfall over the earth's surface; by Mr. Chisholm on the distribution of towns and villages, and on the geographical conditions affecting British trade; by Messrs. Smith, Lewis, and Moss on the geographical distribution of vegetation in England and Scotland; by Mr. Marr on the waterways of English Lakeland; and last, but not least, by Dr. Mill on the Clyde Sea Area, on a fragment of the geography of England, and on England and Wales viewed geographically. It must, indeed, be confessed that in this respect we are still behind Germany, which has been pouring forth a mass of geographical literature of the highest scientific value. But this backwardness is the result of past neglect of the subject, and not of present apathy. There was a current saying a quarter of a century ago that the schoolmaster was abroad. I have shown you that, in a different sense, the geographer was then abroad; but I believe that we may now say that the geographer is at home and has come to stay. There is a whole school of young geographers—not yet very large, it is true, but zealous and active—full of the new ideas, the new methods, the new hopes of our rising science, and I do not think it too sanguine to expect that when the British Association holds its centenary meeting, twenty-five years hence, perhaps in this very city of York, our countrymen will be found to occupy the same position in the front rank of scientific geography that their forefathers held in pioneer exploration.

The following Papers were read:—

1. *Irrigation in the United States.* By JOHN H. BEACOM.

The author began by stating that irrigation contributed largely to the wealth of the leading Powers of the Old and New Worlds, and asked whether it in the end contributed to their downfall; its influence on human society being then briefly considered.

In the United States, west of the 100th meridian of longitude, there are vast areas of unproductive arid land. Ten million acres have already been reclaimed and made very valuable by irrigation, and it is estimated that 50,000,000 acres more (an area equal to that under irrigation in India and Egypt combined) can be reclaimed.

As the result of experience the conclusion was reached in America that the greater irrigation projects could be carried out by the Government better than by individuals, and in 1902 the Reclamation Act was passed, putting the whole matter under Government control. Funds were provided by setting aside the moneys received from the sale of public lands in the arid States. This fund now amounts to 6,400,000£., and it is increasing at the rate of 850,000£. yearly.

Under the provisions of the Reclamation Act Government engineers survey the arid lands, prepare plans for the irrigation works, and construct or superintend the construction of them.

The Government is reimbursed for this outlay by each settler on these irrigated lands paying to the Treasury, in ten or fewer annual instalments, the charges that have been apportioned against his tract. In this way money employed in the construction of works becomes available in a few years for the construction of other works.

Twenty-four projects, as shown below, have been approved, and on thirteen of them work has actually begun:—

Location of Project	Name of Project	Amount allotted and to be allotted this Year	Estimated Cost of completed Project	Acres to be Reclaimed
		£	£	
Arizona	*Salt River	791,123	791,123	175,000
Nebraska-Wyoming	*North Platte	684,270	684,270	100,000
Montana	*Huntley	184,937	—	30,000
„ and M.D.	*Lower Yellowstone	390,423	390,423	66,000
„	Milk River	205,486	—	100,000
Oregon	*Klamath	410,973	821,946	240,000
„	Umtilla	205,486	205,486	20,000
California-Arizona	*Yuma	616,459	616,459	85,000
Nevada	*Truckee-Carson	616,459	1,849,378	400,000
Idaho	*Minidoka	267,132	—	—
„	Payette-Boise	267,132	1,849,378	372,000
Colorado	*Uncompahgre	513,716	513,716	100,000
Washington	Okanogan	102,743	102,743	10,000
„	Tieton	205,486	—	24,000
„	Sunnyside	154,114	—	40,000
Wyoming	*Shoshone	462,344	462,344	75,000
South Dakota	*Belle Fourche	431,521	554,813	85,000
North Dakota	Pumping Projects	205,486	—	80,000
Utah	Strawberry Valley	256,658	—	50,000
New Mexico	*Hondo	49,316	49,316	10,000
„	Carlsbad	123,292	123,292	15,000
„	Rio Grande	41,057	1,479,503	180,000
Kansas	Garden City	53,426	53,426	—

NOTE.—Those marked with an asterisk are under construction. The 'Lower Yellowstone' is treated as two projects.

After considering the engineering and legal features of some of these projects, and touching upon the dispute between Canada and the United States over water rights, the author enlarged upon the Colorado River as the American Nile, and noted the changes in the Colorado desert due to irrigation. The rôle of the Government as an irrigation farmer was considered, and mention made of the investigations and

experiments undertaken by it, and of the aid supplied to inexperienced settlers. The subject of plant immigration and plant breeding was touched upon, and a summary given of the changes in life forms that have taken place during the last thirty years in the western half of the United States.

2. *The Survey of the Scottish Lochs: Summary of Work, 1902-1906.*

By JAMES MURRAY.

Since its institution by Sir John Murray and Mr. Laurence Pullar in 1902, the bathymetrical survey of more than five hundred of the Scottish lochs has been completed. Among these are all the great lakes of the country, and there remain to be sounded only about a hundred lochs, of secondary importance.

Geographical Results.—The Scotch lakes, with very few exceptions, are of elongate narrow form, and none are really great lakes, the largest approaching 24 miles in length. Yet many of the larger lochs exceed 500 feet in depth, and Loch Morar exceeds 1,000 feet. Such depths are comparable with those of the deepest lakes of Europe, and as these are for the most part of much greater breadth and superficial area, the Scotch lakes are relatively very deep. The soundings in general confirm the conclusions previously reached by the Scotch geologists as to the origin of the lakes. Most of the great ones and a large number of smaller ones have the U-shaped section which characterises lakes hollowed out by glaciers. The usual deposit in all the lakes, great and small, is a black peaty mud, the abundant organic matter partly originating in the lakes and partly entering the lakes from the peat bogs, from which much of the water comes. The mineral constituents vary with the locality, and micaceous and quartz sands take the place of the black mud in places. There are also yellow, grey, and red clays, the origin of which has not been studied. It is not known whether these are old strata exposed in the beds of the lakes, or modern deposits at present being formed. The water of most of the lakes is brown and peaty.

Biology.—The outstanding facts which have so far appeared are: (1) The great prominence in the lakes in summer of conspicuous species of Crustacea belonging to the Arctic association of plankton species; (2) The exceeding richness of the phytoplankton, especially in desmids, a fact first brought clearly out by Messrs. W. and G. S. West; (3) The abundance of certain orders of microscopic animals (Rotifera and Tardigrada) at the lake margins. The third fact probably indicates merely the habitual neglect of those orders in lake studies.

Physics.—The physical observations dealt mainly with temperatures and Seiches. Serial temperatures at all depths were taken in all the lochs surveyed, and in Loch Ness an extensive series of simultaneous observations at different parts of the lake was made. The chief outcome of these was the detection of a remarkable seiche (the Internal Seiche).

Seiches.—Observations of seiches were made in many lakes by various members of the staff. The first seiche was noticed in Loch Treig, by Dr. Johnston and Mr. Parsons, in 1902. The detailed study of a few lakes has been undertaken by Professor Chrystal, assisted by Mr. Wedderburn and others. Professor Chrystal has made important contributions to the mathematical theory of seiches, and has besides effected great improvements in the apparatus for observing seiches. The most important of these is the applying of the statorscope to the recording of seiches, by which an exceedingly delicate tracing is obtained.

The Internal Seiche.—Stripped of complexities, the internal seiche may be explained as arising thus: In autumn, when the lake has begun to cool, there is a sharp demarcation between an upper, warmer layer of water, and the deeper, colder layer, which only experiences secular changes of temperature. At this limit, which the Germans call the Sprungschicht, a change of several degrees may occur within a few feet. The effect of a long-continued gale, as shown by Sir John Murray, is to cause an inclination of the upper isotherms of the loch, the depth to which they are affected being regulated by the strength and duration of the wind. At the termination of a gale which has sufficed to cause an inclination

of the Sprungschicht we have this condition of affairs—the cold layer coming nearer to the surface at one end of the loch, and, conversely, the warmer layer attaining a greater thickness at the opposite end. We thus have two fluids of different densities superposed and the line of separation oblique, not horizontal. The temporary equilibrium maintained by the gale ceases with it, and the two fluids are thus free to oscillate. Owing to the slight difference of density of the two layers the period may be very long and the amplitude very great. In Loch Ness, when the Sprungschicht was at a depth of about 250 to 300 feet, the period was about three days and the amplitude as much as 150 feet. This enormous oscillation can only be detected by means of observations of temperature.

3. *A Tour in South-east Persia, with an Account of the Ancient Cities of Narmáshir.* By Major P. MOLESWORTH SYKES.

The tour was undertaken by the author in connection with a commercial mission which reached Bandar Abbás in the autumn of 1904, and spent the last days of that year at Kermán, the capital of South-east Persia.

The start was made in January 1905, and the first night was spent at an altitude of 7,000 feet, in intense cold. The second stage was of extraordinary interest, lying through grim, gloomy defiles shut in by beetling cliffs which towered thousands of feet above. The crux of the stage was an extremely steep pass, from the crest of which the travellers enjoyed a superb view across a succession of rugged ranges to the illimitable Lut, the great desert of Persia.

At Khabís, which is situated in *Garmsir*, or Hot Country, the rigours of winter were exchanged for warmth, and the eyes of the travellers were filled with the beauty of the palm and orange groves, for which the centre is famous.

After a short halt the uplands were again entered, and the large party crossed a waterless stretch of thirty-eight miles in safety. Had the weather been bad, it would have gone hard with the weaker members, blizzards in January at high altitudes being extremely dangerous in Persia.

Bam, a considerable town of 13,000 inhabitants, was the next centre of importance. One striking fact is that from Bam to Quetta—a distance of some 700 miles—there is not a single centre of any importance. This fact speaks for itself more eloquently than any description.

From Bam the district of Narmáshir was entered, and its ruined cities were visited. They are referred to as important centres by mediæval travellers, such as Mukaddasi and Hamd Allah, but have never been identified by modern travellers. The most important of the ruins, the erstwhile famous city of Narmáshir, which was once an entrepot for Khorasán merchants trading with Oman, is now absolutely deserted. Crumbling walls and an artificial mound in the interior, on which the Kush-va-Ran fort undoubtedly stood, are all that is left of what was once a city containing perhaps 40,000 or 50,000 inhabitants.

From Narmáshir the travellers made some long marches through a district without supplies to Rudbár, the Reobarles of Marco Polo, whose route was struck. Thence the Halíl Rud was followed up to the district of Jiruft.

Excellent francolin shooting was enjoyed near the site of Komadin, which is another vast ruin covering an area of several square miles, and is the Camadi of Marco Polo.

From Jiruft the Jabal Báriz range was traversed in safety, although the rivers were in flood, and the party marched to Ráin, and thence to Máhún. The beautiful shrine at this latter centre was founded in honour of Shah Namat Ullá with funds supplied from distant India. This saint, who flourished in the fourteenth century, was a contemporary of Tamerlane, who treated him with great distinction. He travelled widely, and Ahmad Shah, of the Bahmanid dynasty of Southern India, was among his disciples. The prophecies of Shah Namat Ullá are still well known in the Middle East. One of them foretold that Christianity would rule in India for a century, and this saying was undoubtedly a cause, if not a main cause, of the Indian Mutiny. The author referred to the lovely tiled courts where minarets look

down on greenery and water, and concluded his lecture by stating that Máhún possessed a charm for him which was perhaps due to the combination of tiles, greenery, and running water glorified by the turquoise blue of the Persian sky, which he had never seen equalled elsewhere.

FRIDAY, AUGUST 3.

The following Papers were read :—

1. *Coast Erosion.* By CLEMENT REID, F.R.S.

The erosion of our coast must be studied in conjunction with the deposition of the material eroded. When examined in this way we find in England that it has not been a continuous process, varying when short periods are studied, but averaging the same from century to century. Instead of this regular process, the rapid accumulation in certain places teaches us that coast-erosion, as we now see it, began at a definite date, before which conditions were entirely different. If this were not so, the area of the new lands, accumulations of shingle, and of sand-dunes would be much greater. It does not seem practicable to obtain exact measures, but the rates of accumulation of various recent deposits, and of the silting-up of our harbours suggest that the cliff-erosion only began 3,000 or 4,000 years ago, or at about the date when our harbours were already in use and Stonehenge was being raised.

In order to understand the nature of the changes that are now going on, it is necessary to look back to the Neolithic period to see what the country was then like, otherwise the existing irregularities of our coast-line will be quite unintelligible. It is not needful to go back further, but we must picture the country as it looked when the sea stood 60 feet lower.

A close study of the buried land surfaces, or 'submerged forests,' found in the alluvium of all our estuaries at various levels down to about 50 feet below the present sea-level, shows that oak trees flourished on the lowest of these ancient soils. This shows that the sea then stood so far below its present level that the highest tides could not reach the roots of these trees. These old land-surfaces seem all to be of Neolithic date. During this period the seaward end of all our valleys was deepened till the channel reached about 60 feet below its present level. The south and east coasts of England were utterly unlike what we now see. Instead of bold cliffs there was a wide coastal plain, like that which still extends for many miles west of Brighton, separating the rising Downs from the coast. This plain extended out approximately to the existing 10-fathom line.

About 4,000 years ago there set in a fairly rapid but intermittent subsidence of the land or rise of the sea. This subsidence flooded great part of the coastal plain, brought the waves within striking distance of the rising land behind, and submerged the lower part of all our valleys.

The process seems to have been more rapid and jerky than any change which has been recorded of late years, for the deposits in all our big estuaries tell the same tale. We find rapidly deposited marine silt alternating with thin beds of peat or soils with trees. But the vegetation is usually nothing but brushwood or quick-growing trees, and the peat also is of rapid growth. Only at the very bottom of these deposits, far below the present sea-level, are oaks of more than 100 years to be seen.

The rise of the sea-level may have been completed about 3,500 years ago. Whatever may be its exact date, the completion of the rise is the starting-point of our present inquiry. Only then commenced the coast-erosion which we now see; only then did our existing shingle-beaches and sand-dunes begin to form.

At first erosion was rapid, for the sea was merely eating into loose talus or into cliffs of little height; and protective banks of shingle and sand take time to accumulate. As the land is cut into, the cliff becomes higher and shingle-beaches and sand-dunes form, all tending to make the width of the strip destroyed annually less and less.

Of the land thus destroyed part is washed into deep water and lost, but much of the coarser material is rolled into shingle-beaches, or forms sand-banks and dunes. These form our best protection against further inroads. If the coast-erosion is stopped, shingle, beach, and sandbank will themselves wear out and disappear, and valuable lowlands behind may be spoilt by the sea.

Another compensation for the loss on the coast will be found in the great gain of alluvial land in the sheltered estuaries; but against this must be set the rapid silting-up of our harbours, even of those into which no streams flow.

Before we take for granted the desirability of attempting to stop the erosion of our coasts (except near towns) we must strike a balance between loss and gain. If the loss exceeds the gain there will still remain the question, Shall we obtain any sufficient compensation for the enormous cost of any works put up to protect agricultural land?

Some curious problems are suggested by this inquiry. Many may think them of no practical importance, but to the geographer and geologist they are of great interest. If what is said above is correct, and since civilised man has lived in Britain there has been a rapid change of sea-level followed by a long rest—what are the prospects of a similar period of rapid change again setting in? A new rise or fall to the extent of a few feet would have most disastrous effects on all our coasts and harbours, and would also seriously affect our inland drainage until things were adjusted to the new conditions.

2. *The Study of Social Geography.* By Professor G. W. HOKE.

The author discussed the following theses:—

1. Geography is the science of distribution.
2. Geographic science is best served by a study of the *causes* rather than by a study of the *effects* of distribution.
3. Geographic factors need not be *facts* of distribution.
4. The factors of social distribution are *historic* and *psychic*, as well as environmental.
5. The student of geography must have a clear-cut notion of the limitations of the field, and to prevent hopeless confusion it is essential that he keep constantly in mind the relation of the special subject of investigation to the field of geography as a whole.

3. *The Structure of Southern Nigeria.* By JOHN PARKINSON, B.A., F.G.S.

After remarking on the tentative nature of this communication, owing to so large a part of the colony having been unvisited by him, the author defined as of fundamental importance the boundaries of the crystalline rocks.

The southern boundary of these rocks, which are by far the oldest member of the rather limited series found in the colony, forms a rude semiellipse, indented on the east by the complex of the Oban Hills, and crossing the Niger in lat. 7° 19' N. (Gürich). As far as Southern Nigeria is concerned outliers of the sedimentary series do not occur, or have not yet been found. The researches of Esch and Solger have proved the occurrence of Cretaceous rocks in the Kamerun, and during the past three years these have been traced westward, by the Mineral Survey of Southern Nigeria, round the base of the Oban Hills, up the Cross River to Abakalliki, the most northerly point yet reached in the eastern province. The appearance of the country as seen from Abakalliki suggests that the Cretaceous strata extend northward for another thirty miles. Their westward extension, whether of surface or sub-surface, remains to be definitely fixed, though they probably extend from Afikpo to within fifty miles of the Niger as the dominant formation. Westward from Asaba to Benin City and Ifo, and through the Ijebu country to Abeokuta, the country is an undulating plain, consisting entirely of rocks later than Cretaceous in age. From geological considerations which are foreign to this

paper the author concludes that we have here beds representing, not a continuous sequence, but a series of episodes in the Tertiary history of the country.

The geography is, of course, directly related to the lithology and the geological history of the rocks. Four distinct types of country have to be studied: the first is that built up of complexes of crystalline rock; the second, that formed by the Cretaceous strata; the third, composed of Tertiary beds, the most conspicuous of which are the red sandy clays typical of Ijebu and Benin; the fourth, still in process of formation, of the delta and mangrove swamps. Each of these exhibits physical features peculiar to itself and not shared by any other member of the series.

Brief reference is made to the salient characteristics of each group. In the Oban Hills we find an unorientated group of peaks, attaining an elevation of rather over 3,000 feet, characterised by steep slopes and drained by a rejuvenated river system. The best example known to the author of the second type of scenery is that between Afikpo and Abakalliki, where the effects of erosion on a group of strata of varying hardness, folded by a north and south movement, are admirably seen. This is an open country of the orchard type, most assiduously cultivated, but on the northern and southern slopes of the Oban Hills the Cretaceous rocks are covered with dense bush, which masks the physical features. The country formed by the softer red loams and sands characteristic of parts of the central and western provinces is exceedingly monotonous, covered with heavy bush and drained by a very mature river system.

The watercourses are greatly encumbered by sandbanks. Near Asaba we find low hills, but for the most part, *e.g.*, between Ifon and Sapele, the surface is gently undulating. In regard to the delta region, probably in reality this is not as flat as it appears from the sea, for inliers of the red sands of Benin, forming low hills and surrounded by mangrove swamps, are not uncommon.

4. *The Visit of the British Association to South Africa.*
By H. YULE OLDHAM, M.A.

MONDAY, AUGUST 6.

The following Papers and Reports were read:—

1. *Geographical Photography.* By JOHN THOMSON.

2. *Report on Investigations in the Indian Ocean.*
See Reports, p. 331.

3. *The Percy Sladen Expedition in H.M.S. 'Sealark': The Chagos Archipelago.* By J. STANLEY GARDINER.

The Chagos Archipelago is perhaps the least known coral region in the world. Situated nearly 5° to the south of the Maldives, from which it is separated by over 2,000 fathoms of water, its bank within the 1,000-fathom line covers about 21,000 square miles. In this area arise a series of shallower banks, separated by 300 to 800 fathoms of water, varying from approximately flat submerged shoals at 20 fathoms or less to large, more or less complete, ring-shaped surface reefs, or atolls. The whole is probably part of a large land mass which connected Madagascar to Southern India up to the commencement of the Tertiary period (Eocene). The submerged banks are believed to be gradually assuming the atoll-shape by coral and algal (nullipore) growth on their edges. If the existing atolls have been

formed from such shoals—and this is probably the case—they show in a marked manner an accompanying increase in depth in their centres by solution, tidal erosion, &c., some lagoons being 40 to 50 fathoms deep.

Land on the encircling reefs of atolls may be formed either by the piling-up of coral masses from the reef-flats or by some change of level of the reefs in respect to the sea. Both methods are found in the Chagos, but there is evidence in every atoll of some apparent upheaval. This alteration of level would appear to be universal throughout the Indo-Pacific coral-reef regions (lat. 30° N. to lat. 25° S.), the required amount varying from 5 to 35 feet. Since the phenomenon is so widespread, and there is evidence of many local upheavals throughout this zone, it would seem to be due to some withdrawal of water from the Equator rather than to any change in level of the ocean floor. The causes of this are probably to be found partially in the attraction of continental masses on the water, but mainly in the piling-up of ice in the south polar regions.

The lagoons of the atolls are generally increasing in size at the expense of the land, that in Diego Garcia being fringed for a great part of its circumference by low cliffs. Remains of land are found at the edges of the Salomon Reefs towards the lagoon, where the bottom drops almost perpendicularly from one to four or five fathoms. This further clearly indicates an enlargement of the basin at the expense of the encircling reef-flats. Boring and land-triturating organisms are almost as conspicuous destructive agents as in the Maldives, and the tides are of great importance in removing fine sand and washings from the lagoons. Practically no coral masses are swept off the encircling reefs into the lagoons, growing animals and plants alone tending to fill them up.

The reefs throughout the Chagos are extending seawards by means of corals and nullipores, the latter acting mainly as consolidating agents, but practically forming the whole edge below five fathoms. The foundations for these—true reef-building corals only live down to 35 fathoms, and nullipores down to 60 fathoms—are formed by masses from the shallower parts of the reef above swept outwards by under-currents. The reefs in fact are everywhere spreading outwards on the piled-up remains of their own organisms.

The reef animals are as abundant as in the Maldives or Seychelles, but their variety appears to be considerably less. In fact the Chagos is thoroughly oceanic in its reef fauna, showing no trace of any former connection with continental slopes. The land animals and plants are such as might be expected on any isolated oceanic islands, but the vegetation is further restricted owing to the islands being purely of limestone formation.

4. *The Geography of the South Orkneys and other parts of the Weddell Sea.* By R. N. RUDMOSE BROWN.

5. *The Limestone Caves of Western Australia.*
By Professor W. B. BOTTOMLEY.

The cave country of Western Australia is situated in the south-western portion of the State, between Cape Naturaliste and the Leeuwin, and extends over an area of some sixty miles. The whole district is honeycombed with subterranean galleries, only a few of which have as yet been explored. All who have visited these caves are enthusiastic over their marvellous features, and those best qualified to express an opinion state that they are infinitely grander than the famous Jenolan Caves of New South Wales, and are unrivalled for their beauty, picturesqueness, and infinite variety in the whole world.

A drive of twenty miles from Busselton, the terminus of the South Western Railway, 150 miles from Perth, and the first known cave of importance is reached.

Yallingup Cave.—Entered by a shaft about 30 feet deep, and formed of a series of chambers extending for nearly four miles. Each chamber has its own

special wonders and curiosities, as shown by the names given: 'The Chamber of Mysteries,' 'The Cascades,' 'The Shawls,' 'The Jewel Casket,' &c.

Wallcliffe Cave.—Situated close to the mouth of the Margaret River, is the oldest known of the caves, noted for the figures called 'The Poultry and Fruit Show.'

The Blackboy Hollow Cave.—Only partly explored, contains 'The Queen's Crown,' 'The Organ Pipes,' and the 'Mammoth' stalagmite.

Witchcliffe Cave.—One of the smallest of the group.

Calgardup Cave.—A descent of 100 feet leads into a series of chambers of indescribable beauty. The wonders are: 'The Suspended Dome,' 'The Crystal Terrace,' 'The Weeping Rock,' and the marvellous 'Meteoric Shower,' consisting of thousands of slender stalactites of varying length, each capped with a star-shaped terminal.

The Mammoth Cave.—So called on account of its majestic proportions and its colossal formations. Noted for 'The Eagle's Wings,' 'The Organ Pipes,' and 'The Mammoth Shawl.'

The Lake Cave.—The only one explored of some nineteen caves known to exist within a radius of two miles. The entrance is through a circular hollow 300 feet deep. The cavern contains one of Nature's greatest masterpieces—'The Suspended Table.'

Yanchep Caves.—These recently discovered caves were partially explored by Mr. C. P. Congrave in February 1903. Some thirty caves are at present known, many possessing chambers remarkable for their beauty and grandeur. The whole country round is honeycombed with caverns, and the Government is about to undertake a systematic survey of the district, when doubtless new wonders will be revealed.

6. *Interim Report on Rainfall and Lake and River Discharge.*

See Reports, p. 330.

7. *Past and Present in Asiatic Turkey.*

By Professor W. M. RAMSAY, D.C.L., LL.D., Litt.D.

I. The geographical situation of Asia Minor is noteworthy as bridging the sea between Asia and Europe, and its importance in world-history arises out of this situation.

II. The conquest by the Turks, (1) Seljuk and (2) Osmanli, meant the reduction of great part of the country from the settled and civilised state to a semi-nomadic stage of society.

III. A distinction is to be noted between the nomads, or Turkmen, and the city Turks (now called Osmanli). This distinction is as old as the first Turkish invasion. The nomads were the real conquerors of the country, and they were practically independent and hardly part of the Turkish State until comparatively recent times. They spread like a flood over the land and submerged it.

IV. In the cities the industries of the Roman Empire survived. Most of these industries gradually and slowly died out, drowned by the flood of nomadic barbarism. Some of them survive to the present day. Some lasted till within the memory of men still living. Some died long ago. The chief cause of their destruction was the difficulty of communication over the country. While the cities at first retained their old standard of civilisation, they were divided from each other by the sea of barbarism and nomadism. In earlier Turkish time trade passed with difficulty from city to city by aid of the large and splendid khans, which the Seljuk Sultans built at intervals along the chief roads. These khans, though often very beautiful as buildings, were not a proof of civilisation, but of the submergence of civilisation. They were fortresses, in which caravans might rest safe from the nomads at night: tiny islets in the sea of nomadism.

V. The land to a great extent passed out of cultivation; irrigation was destroyed in most places; land became stony, destruction of terracing, &c.

No possible cure except generations of peasant proprietors. The olive, the tree of civilisation, almost ceased to be cultivated except where the Greeks constituted the main body of the population.

VI. A revival of prosperity has taken place in recent times. The chief cause is the restoration of communication, partly through railways, partly through road-making. From this spring all the other causes, which are superficially more conspicuous. Industries have revived, as is exemplified by the enormous growth of the carpet trade; the spread of an industrial population along the railways that lead inland from Smyrna; the handkerchiefs of Bulladann. Agricultural development is to be seen in the growing of cotton and the collecting of liquorice-root, and the reclamation of waste land around Smyrna by giving allotments to *bona-fide* cultivators.

VII. The Bagdad Railway is an important factor as regards the future. The paper discussed the character of the line in Asia Minor; the religious ceremony at the inauguration; opening of the first section; prospects.

TUESDAY, AUGUST 7.

The following Papers were read:—

1. *Proposed Remeasurement of Geodetic Arcs in the United Kingdom.*
By Major E. H. HILLS, C.M.G., R.E.

The fundamental triangulation of Great Britain and Ireland was completed fifty years ago. Though excellent work for the time at which it was done, it is now far behind the standard of modern work of its class.

The result of this inferiority is that the British work cannot be co-ordinated with the Continental series for the purpose of geodetic discussion, such as a determination of the figure of the earth. This defect is all the more noticeable in that the necessary observations to connect the two series were actually made at considerable expense. To remedy this defect, which may justly be described as a standing reproach to British science, it is by no means necessary or desirable to reobserve the whole original network of triangulation. What is required is to connect geodetically, by as good a set of triangles as can be selected, the three extreme points of our islands, viz.—(1) Saxavord, the northernmost point of the Shetlands; (2) Valentia, on the west of Ireland; (3) the stations on the coast of Kent trigonometrically connected with France.

Were this work done we should have completed, as far as lies in our power, two very important lines of geodetic triangulation—namely, the meridional arc, through the longitude of Greenwich, and the longitudinal arc, along the parallel of 52° north latitude.

At present, without including Great Britain, these arcs extend from the north-east corner of France to Ain Sefra in Algeria and to Orsk in Russia respectively, amplitudes of 18° and 57°.

With the British work there would be available added amplitudes of 10° and 11½° respectively. Geodetic work is now much more rapid, as well as more accurate, than when the triangulation of England was done. The invention of invar has enormously simplified the difficult operation of base measurement, and the theodolites, for making the angular measurements, can now be obtained more precisely graduated and of a design altogether superior to the older forms. The general result of these improvements is that, while a much higher standard of accuracy can be realised, the rate of progress of such work has been increased in an even higher ratio.

The work should be done by the Ordnance Survey Department, which is, it is believed, quite ready to undertake it; and the powerful influence of the British Association might justifiably be exerted in persuading the Treasury to grant the requisite funds. The total cost would be quite trifling compared with the existing national expenditure upon survey work.

2. *A New Form of Tacheometer or Range Finder.*

By E. A. REEVES, F.R.A.S.

This instrument consists of an ordinary inverting telescope mounted on a slide, much like the bed-plate of a lathe, the whole being supported by a tripod-stand. In the diaphragm of the telescope are two vertical wires, and the distance of an object is obtained by first turning the telescope with the slide until the object is made to coincide with the left-hand wire, and then moving the telescope along the slide until the same object appears exactly on the right-hand wire. The length of the slide necessary to bring the object from one wire to the other gives the distance at sight, the amount of slide being in direct proportion to the distance of the object. Instead of the telescope being fitted with fixed wires and carried on a movable slide, the instrument may be so arranged that the base is a fixed length, having a telescope at each end fitted with a vertical and horizontal wire, the right-hand telescope having an additional movable vertical wire, made to move across the diaphragm by means of an ordinary micrometer screw. To use this form of the instrument, as before, turn the rod, until the vertical wire of the left-hand telescope intersects the object observed; then, looking through the right-hand telescope, turn the head of the micrometer until the movable wire also intersects the object, when the numbers registered on the drum of the micrometer, aided, if desired, by a table, will give the distance of the object. Errors in adjustment or those caused through imperfections in the lenses, will be eliminated if, after taking the first observation, the operation is repeated with the telescopes and base reversed, as in 'face left' and 'face right' readings with a theodolite. Either form of the instrument can be fitted to a theodolite.

3. *A Journey in the Central Himalayas and Adjacent Parts of Tibet.*

By T. G. LONGSTAFF, M.A., M.B.

This journey was undertaken during the summer (May to October) of 1905. The primary object was mountaineering, and the writer was accompanied by an Italian alpine guide and a porter. The distance travelled was about a thousand miles. Kumaon was first visited, and the eastern glaciers of the Nanda Devi group were explored, heights of over 20,000 feet being attained by the party. The extreme north-west corner of Nepal was next visited, in order to examine the glaciers to the north of Nampa. By the kindness of the Indian Government the party were allowed to accompany Mr. C. A. Sherring on his political mission to Western Tibet.

Entering this country by the Lipu Lekh Pass (16,780 feet), Purang (Taklakot) was reached on July 15. Leaving the mission here, the writer spent a week on Gurla Mandhata (25,350 feet), reaching heights of about 23,000 feet. The glaciers and valleys of this group do not seem to have been previously visited. Rejoining the mission at Mansarowar Lake, the whole party passed along the neck of land separating that lake from Rakas Tal, and examined the channel, seen by the brothers Strachey, between the two lakes.

Passing close to the sources of the Satelej, the two parties separated at Missar, Mr. Sherring proceeding to Gartok, and the writer making his way to Gyanema, and thence to Shipchilam. On August 28 the Chor Hoti Pass (18,500 feet) was crossed into Garhwal. Following the course of the Dauli River, Gwaldam was reached in September, and at the beginning of October a reconnaissance was made up the Kuramtoli glacier at the foot of Trisul.

4. *The Climate of the Wheat Area of Central Canada.*

By Professor L. W. LYDE.

In this area we have a typically continental climate modified by latitude and lakes: a long summer day, slow rotation of earth, chinook winds. The operation of these factors is seen in the character of the forest.

Spring is sudden and short, being limited, as far as wheat-cultivation is concerned, to the four weeks in April, when there is an average daily maximum of about 50° F., the east being 5° colder than the west, where snow is not 'packed,' and is therefore easily licked up by the chinooks.

With unit of population = one family of five persons (at least two of them males), the maximum of plough, harrow, and drill that can be 'risked' = 80 acres in the four weeks.

Summer is the rainy season, beginning with mid-May rains and ceasing with mid-August dry spell. Temperature rises steadily May-June with rain: Winnipeg district has more than half, Qu'Appelle and Prince Albert districts have more than three-quarters, of the total rainfall in the three 'growing' months (May, June, July).

Mean temperature (June-August) on Brandon-Battleford curve is 62°·5 = that of best English wheat land.

Duration of sunlight varies from about 15½ hours per day at mid-summer in Winnipeg district (averaging one hour per day more than Chicago district from June 15 to July 1) to over 17 hours at Prince Albert, with very high percentage of bright sunshine (result, a fine-coloured grain), especially along Brandon-Battleford curve.

Duration of night.—Short night = short time for radiation, but comparatively long 'cool' spell, which is as favourable to wheat as it is unfavourable to maize (and mosquitos).

Autumn is a dry season: (a) August, harvest. One family can bind and stook 70-80 acres in one week (if there is a third male can cart same in a second week to central stack, and have the equivalent of 1,200 bushels of grain ready for thresher by the end of August); (b) September, average temperature drops 10° F., and 70 hours of bright sun is lost; October drops 10° F. more. Therefore it is desirable to plough at once. Loss of 'fall' plough means loss of early seeding the following year, = loss of yield per acre, loss of weight per bushel, loss of market by water transport.

Winter.—Length and intensity of cold do not affect the north limit of wheat in summer, but guarantee cleansing of ploughed land and leave no excuse for grain not being also clean.

5. *The Zambezi beyond the Falls.*

By A. TREVOR-BATTYE, M.A., F.L.S., F.R.G.S.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS,

PRESIDENT OF THE SECTION.—A. L. BOWLEY, M.A.

THURSDAY, AUGUST 2.

The President delivered the following Address:—

FROM 1835 to 1855 Section F of the British Association was devoted to 'Statistics,' and it is only from 1856 onwards that it has received its curious name, 'Economic Science and Statistics.' It is interesting to recall that Babbage was its first President, and that in its earlier career such well-known pioneers in the application of statistical method to industrial phenomena as Porter and Tooke occupied the chair. In its later course economics and statistics have shared the honour with public administration, whether related to trade or finance; and in recent years the professorial economist has alternated with the official administrator. It may be hoped that a new category will soon be added to the interesting and varied list—that of those engaged in practical or applied economics, the organisers of the army of industry; and in this connection it is much to be regretted that Sir George Gibb was unable to take the place which I now occupy. With a list which includes the names of Baines, Newmarch, Chadwick, Jevons, Booth, Giffen, and Edgeworth, no complaint can be made that statistical science and statistical art have not been worthily represented, and it would seem that there was no species of the exponents of our group of sciences not already scheduled in this roll; but I find that I have the unique position of being the first professed—or, shall I say, armchair?—statistician, with few economic credentials, to hold this position; and this fact leads me to direct my address mainly to the claims of statistics to be an exact science, worthy to rank as such with those which form the subject-matter of Sections A to L. Since, however, the title of our section and the names of its officers, past and present, suggest the essential connection of economics with statistics, and the establishment of both on a quadruple basis of theory, history, experiment, and practice, my intention is to show that our work resembles the natural sciences in the respect that the most delicate researches in theory lead directly to visible and important practical results. The graduation of the income-tax, the supply of fish in the North Sea, and the expenditure of a labourer's wage, are among the subjects to which I have recently had to apply mathematical statistical analysis.

It is a long step from Arthur Young's tours to Professor Edgeworth's 'generalised law of great numbers,' but there is no distinction in the nature of things between arithmetical and mathematical statistics; the distinction to be made is not between the various methods of accumulating and tabulating data, but between the truth and falsity of the reasoning based on the tabulation. Mathematical treatment in the end only furnishes us with a microscope to observe differences which are blurred to the naked eye of arithmetic, and with a method

of measurement to aid the judgment too immature to seize the significant fundamental fact concealed by its diverse manifestations. Purely arithmetical work is, however, limited to the tabulation of exact records, where the whole field to be surveyed can be covered, where no approximation or interpolation is necessary, and where statistics becomes only another name for accountancy; whereas the application of mathematical principles makes it possible to measure the inaccessible, to describe the animal from the single bone, to make firm observations from a shifting base, to dispense with the fixed meridian which the base practice of industrial and official needs obscures.

Great progress has been made in recent years on what I am calling the arithmetical side of statistics. With the encouragement of the very careful work done by the International Institute of Statisticians, whose labours have been mainly in this direction, official statisticians are aiming at logical systems of classification, on such natural lines as may be applicable for the majority of civilised nations and for long intervals of time. There are many difficulties in this direction: economic categories—such as skilled and unskilled labour, manufactured goods and raw materials, animal or vegetable products, occupied or unoccupied—do not admit of such simple definition as divides an acid from an alkali; statistical definitions are rather the delimitation of boundaries, and it is a matter of convention on which side particular persons or things are to be placed. Different conventions have become established in different countries, and the rapid change of conditions frequently induces an alteration in the conventions of a single country. Progress is being made in the direction of uniformity as between country and country, and it is here that the classifications of the International Institute are so important. It is still the case, however, that we are so far from agreement, that it is impossible to understand the published statistics of this or any other country without intimate knowledge of the methods of compilation and classification in each group. The comparison of wages or prices, for example, in England and Germany is so difficult as to be hopelessly misleading, except in the hands of those few who have made a special study of these statistics in both countries.

It has till recently been the custom of departments publishing statistical returns to issue them without explanation of the particular conventions adopted, and then to complain that the ignorant public misquote them, till there was a danger that statistics should be issued only by officials for officials, and even by an official for himself alone, while the use of them (necessarily erroneous) by the general public was regarded as objectionable trespass in a private preserve. The growth of popular interest, and of a certain blind and misguided confidence in statistical statements, resulted in the printing of cautions that the statistics did not mean what they appeared to mean; and thus boards were erected to the effect that this table was dangerous to statisticians and newspaper writers should drive with caution; but it did not for long occur to those responsible that it was their business to put the public roads in good order for the convenience of travellers.

The Board of Trade—and especially the Labour Department—have gone a long way now in the direction of explicitness of statement as to the exact meaning of their tables, and of carefully-thought-out improvements in classification and nomenclature; and herculean efforts have been made to improve the Occupation Census, the difficulties of which task have hardly been realised by its many critics. The returns on a greatly altered basis for 1901 illustrate the permanent dilemma that compilers of periodic returns have to try to avoid. If the old classification is retained, modern conditions throw it out of date; if a new one is adopted, comparisons may be made impossible. In 1881 veterinary surgeons and farriers were classed together in the Census list of occupations; in 1891 the latter were put under 'Workers in Metals,' and in West Ham (for instance) were included under the heading 'Blacksmiths and Whitesmiths.' In 1901 whitesmiths are merged either in 'Others in Engineering' or in 'Miscellaneous Metal Trades,' blacksmiths are given together with 'Strikers,' and the whole group of metal industries rearranged. The result is that in comparing 1881 and 1901 the smallest comparable

group must comprise all workers in metals and veterinary surgeons together. The old classification, so far as it is retained, still leads to curious anomalies. The word 'postman' does not occur even in the detailed list of occupations, and it is a doubtful question whether a telegraph-boy is not considered as occupied in 'The Government of the Country,' while the post-office clerk is engaged in the 'Conveyance of Men, Goods, and Messages.'

It is a sad reflection that, while so much care and labour are spent in accumulating and printing statistical tables, so few of them are of any real importance, and so few are intelligible, even to one who studies them carefully. This topic was handled so ably by Professor Mandello in London last year¹ that it is only its great and immediate practical importance that leads me to refer to it. We need a central thinking department in statistics. There is already collected by the various Government departments, partly in their routine work, partly for the dissemination of information, an immense amount of valuable facts: but whenever a scientific inquirer endeavours to describe accurately some social or industrial development, or wishes to bring to the test of statistics the effect of some proposed reform, whether in taxation, regularity of employment, care of young children, or whatever it may be, some essential information is found lacking, for the reason that it has been no one's business to collect it. The details of returns of income remain uncodified in the offices of the local surveyors. Baxter's first estimate of—or, rather, guess at—the amount of income below the exemption limit still holds the field, for no inquiry has ever been made, and we continue in our ignorance of the aggregate national income and of its distribution. We have no adequate knowledge of the age, physical condition, or former occupation of the persons who receive public relief. Illustrations such as these could be multiplied by everyone who has tried to use official statistics. Owing to the enterprise of the Board of Trade, we are to have a second Wage Census and an Industrial Census, and thus many important gaps will be filled in; but there are as yet no signs of the consideration of the general question of what statistical measurements of the wealth, industry, occupations, and physical condition of the nation should and can successfully be undertaken.

Official publications have in general been restricted to arithmetical statistics, except in the case of the Table of Survivors in the Census reports, and quite recently to the measurement of the significance between the death-rates of different occupations in the Registrar-General's report on Scotland. The official view appears to be, quite correctly, that nothing should be published under the sanction of Government which is not an ascertained fact; but the briefest study is sufficient to show that the very nature of the measurements which have to be made, if only because of the necessary arbitrariness of definition, precludes exactness. The result is that the official counting is numerically correct, but the things counted are not coextensive with the quantity that the scientific inquirer needs to measure. He is left in the position of a man who inquires a distance in France, and is told that it is 8543 kilomètres along the high-road, and then some way along a path; the precision of the first measurement is useless to him. It must be recognised that most statistics are necessarily approximate; and just as in other scientific measurements the quantity is given as correct to so many significant figures, so in statistics the possible and probable limits of error should be estimated, and the false show of so-called mathematical accuracy given up.

It is in this direction that the application of mathematical methods is necessary; but before dealing with them I wish to consider the provision made for the supply of persons capable of dealing with statistics by scientific methods.

I have made inquiries at the principal universities of the United Kingdom, with a view to ascertaining what facilities were afforded for the study of statistics, whether arithmetical or mathematical. A knowledge of the statistics of trade and some acquaintance with the main sources and ordinary non-mathematical methods of statistics is required in the Faculties of Commerce in Manchester and

¹ See *Journal of the Royal Statistical Society*, 1905, pp. 725 seq.

Birmingham, and the nature of averages and index numbers is dealt with in lectures and examinations. In Manchester statistics may be taken as one of a long group of special subjects. In Liverpool elementary knowledge of statistics is expected of students in economics, and an effort is now being made to introduce a course of statistics. In Glasgow and in Edinburgh statistics has no formal place, but an attempt is being made in the latter city to recognise it. In Dublin part of the ordinary lecture course is devoted to elementary statistical methods, and the subject 'Elements of Statistics' counts as an essential part of the examination for the annual prizes in political economy; the questions are non-mathematical. At Cambridge statistics is not distinguished as such in the syllabus for the Tripos in Economics, though statistical methods are implied in the Part II. papers on 'Advanced Economics, mainly Analytic.' So far as I can learn, there is no provision in lectures or examinations at Cambridge or Oxford for the application of mathematics to statistics. More complete recognition is given in the Faculty of Economics in London. There statistics up to the point reached in Birmingham and Manchester is demanded of all Pass students, and a considerable amount beyond is expected of those who have preferred mathematics to logic in their first year. Regular courses of lectures are specially devoted to the subject in two of the constituent colleges or schools of the university, and a large number of students have passed through them. Though the mathematics required stops just short of the infinitesimal calculus, there is no such limitation in statistics as one of eleven possible special subjects for honours.

It may reasonably be held that the application of mathematical reasoning to tabular information is so special a subject that it may safely be left to post-graduate study and individual initiative for men who are working at so wide a subject as political economy or taking a practical course in commerce; but no one can, I think, reflect seriously on the statements just made without coming to the conclusion that, in view of the immense importance attached to statistical reasoning in modern times—whether in trade disputes, or in proposals for social reforms, or in political pamphlets and speeches, or in the public Press—men who have not mastered the main criteria of the adequacy of such statements, who are not acquainted with the possibilities of such measurement, and who do not know the main statistical facts already common property, are not completely prepared in their professed subjects, and that there is not much likelihood that they will obtain this knowledge while the universities give so low a formal place to, and so little organised teaching in, these subjects.

If, however, it is admitted that the Pass student in economics cannot be expected to have more mathematics than is required for matriculation, and that there is not a sufficient demand for a course which shall apply more advanced analysis to economics and statistics, we might expect that other means would be taken to supply the country with those expert statisticians that so many public departments, whether central or local, so obviously need. Those responsible for the syllabus for First Division clerks in the Civil Service were not of this opinion. Out of twenty subjects, political economy is one, and in its syllabus the application of statistical methods to economic inquiries is named; but only two questions have been set in the last three years, and these do not involve mathematics. Mathematics itself occupies a conspicuous place, but there is no sign that its application to statistics or the theory of probability are included. It may be said that the examination is intended to be a test of non-specialised education, and that technical methods are best studied in the departments themselves. But though I find that the Record Office demands a knowledge of history and of a language from its recruits, there seems no evidence that an adequate knowledge of mathematics is required among those who are drafted to offices where the public statistics are handled. It may happen that those who are responsible for statistical analysis have gained high honours in mathematics; but in the existing routine it seems just as likely that they gained their distinction in Latin verse or mediæval history. Should a department discover that the handling of statistics did not come naturally to an ordinary educated person, it can perhaps fall back on the seventh clause of the Order in Council of 1870; 'In case the

chief of a department to which a situation belongs . . . shall consider that the qualifications in respect of knowledge and ability deemed requisite . . . are . . . professional, or otherwise peculiar, and not ordinarily to be acquired in the Civil Service, a person ' who has acquired such qualifications in other pursuits ' may be appointed.

I have dealt with this subject at length in order to ask the question: Have we any guarantee that the public service, whether official or unofficial, will be supplied with a sufficient number of persons who are qualified to handle statistics expertly, to follow the rapid mathematical developments which alone can get the full significance of records, and to inform the public with reasoned knowledge of the measurable phenomena of national life? There is no dearth of capable mathematicians streaming from our universities, but there are relatively few who apply their special knowledge to public affairs; they rather dissipate it in elementary teaching or put it aside as a useless weapon. There is a very plentiful supply of expert arithmeticians entering the lower grade of the public service, but there is no provision for their developing into educated statisticians.

The use of mathematical reasoning in statistics is very imperfectly understood, partly because the passage from numbers to symbols and back to numbers suggests an air of mystery, or even of prestidigitation, to the unmathematical mind; partly because, even with mathematicians, the application of the theory of probability to the determination of the precision of an estimate is unfamiliar; partly because the method, though fully sixty years old,¹ has only recently been developed, and the methods and limitations of its use are still a matter of analysis and discussion among its advocates. In many respects its position resembles that of mathematics in economic theory, a subject handled at length by Professor Edgeworth, my predecessor in this chair in 1889. There are those that hold, in both cases, that verbal or numerical reasoning, unassisted by symbols, is sufficient for the elucidation of all truth. Whatever may be said in favour of this view as regards economic theory—a discussion so familiar to my audience that I need not dwell on it—I do not think that in the case of statistics the argument can be seriously maintained, and it is my intention to give such reasons for this statement as the limitations of a presidential address make possible.

Scientific measurement is in general approximate, and in the physical sciences much attention is given to the determination of the accuracy of experiments, and their result is given as not absolute, but as correct to so many significant figures. Statisticians frequently find that their second significant figure is doubtful, as in the case of the national income, which is estimated as between 1,700,000,000*l.* and 2,000,000,000*l.* Sometimes even the first figure is doubtful, as in the erroneous quotation that 13,000,000 persons are on the verge of hunger. In such cases as this the physicist would stop, and set to work to elaborate his measurements. Not so the popular statistician, who delights in guessing in tens of millions and mixing up these bold round numbers with others correct to ten significant figures. These guesses must be rigorously excluded from serious work, and, lest they should come in unawares, the exact limitation of the quantity actually measured and its relation to the total in question must always be carefully studied. We must candidly accept the fact that our raw material is imperfect, and our business is to remove the imperfections so far as we can, and, above all, to measure those we cannot remove. It is in these two directions that mathematical methods are generally necessary, and sometimes sufficient. The material is improved by methods of interpolation and graduation; the general law of grouping or direction of movement is discovered, and the accidental variations eliminated; or, conversely, the general direction is neutralised and the variations measured. The adequacy of the material is discovered from internal evidence of consistency and conformity to the laws of continuity, and improved by carefully selected samples. The last-named method will be dealt with presently.

When the material is improved and tested there arise questions of causation—

¹ Quetelet's *Lettres sur la Théorie des Probabilités* was published in 1846.

as to whether two series or groups are connected, or whether the observed variations are independent, or as to whether a difference between two measurements is significant or the accident of observation, or as to whether a change observed in average or grouping can be accounted for without assuming a change in the plexus of causes governing the phenomena.

It may be well to give commonplace instances of each of these methods. The ages of persons, as tabulated from the Census forms, are systematically smoothed for the Table of Survivals. Records of prices are averaged to give index numbers independent of individual variations. Records of unemployment are averaged to give the seasonal variation apart from the general trend. Records of wages may be rejected or doubted if they show too close a grouping at round numbers, if the grouping found in two similar establishments is markedly different, or if the relation of the various grades is not that obtained in properly chosen samples. The relation between infantile mortality and the employment of married women is a problem in correlation very difficult from the dearth of data. The observed difference in death-rates in two occupations requires a delicate mathematical test before it can be established as a real phenomenon. The proof that a known change in tariff has or has not affected prices or trade requires an adequate measurement of the variations when there has been no such change. The question whether the national income has in recent years become more or less uniformly distributed supplies a mathematical problem of considerable difficulty. Most of these illustrative problems can be treated arithmetically; the essential thing to observe is that the choice of the right method of treatment requires mathematical analysis.

The time is not ripe, nor have I the knowledge, for writing the history of mathematical statistics; but a slight sketch may be offered of some of the main developments, from Gauss and Laplace to Quetelet, and to Professors Edgeworth and Karl Pearson. I leave on one side the mathematics of graduation and interpolation, Newton's interpolation formula, Farr's life table, Hain's application to the smoothing of statistical series, and Mr. Sheppard's central differences; and I omit references to the method of least squares, used by Gauss in 1795 and Legendre in 1806, since this has been developed on non-statistical lines and its statistical use is merged in the development of the law of error.

The fundamental formula of the normal curve was known at least as early as 1809. Hagen (of Berlin) used it in 1837, deducing it from the binomial form. In 1837 Poisson defined 'the law of great numbers,' a phrase whose meaning has been enlarged by Edgeworth. In 1846 Quetelet showed its very extensive application to anthropometry, and enriched his letters with illustrations culled from a very wide field. In the same year Bravais discussed the surface of error for two variables. In 1852 Hain (of Vienna) applied Quetelet's method to the observation of the constancy of many important statistical totals and to the measurement of their variation. He measured the deviation by the method of mean square

$\left(\sqrt{\frac{\sum d^2}{n}}\right)$, whereas Quetelet had dealt mainly with the binomial measure

$(\sqrt{2pqn})$. In 1877 Lexis showed the importance of the difference between the two methods of measuring deviation just stated, and applied the law of great numbers to the ratio of male to female births and to the normal span of man's life (a subject continued in Professor Karl Pearson's 'Chances of Death'). In 1885 Professor Edgeworth brought into prominence the means of testing the significance of observed differences between the averages of kindred groups, and showed the very large practical field of possible applications of this and other methods based on the law of error. More recently, and especially in the last ten years, the theoretical foundation and the extensions and modifications of the normal law have been examined and the formulæ developed. The skewness of the binomial form is shown in Laplace's formula (1814), and was commented on by Quetelet (in 1846); Poisson gave the second approximation to the normal curve; this has been developed, varieties of treatment suggested, and further approximations given, by Fechner, Lipps, Bruns, Werner, Ludwig, Charlier,

Kapteyn, and especially by Edgeworth, who has arrived at a temporary conclusion of his labours this year in his analysis of the complete form of the law of great numbers and of the conditions under which it may be expected to hold. On the other hand, mathematical formulæ on a double basis of *à priori* hypothesis and of empirical justification have been elaborated (primarily for biological purposes) by Professor Karl Pearson, whose method of fitting by moments has proved fundamental for work of this kind.

The measurement of correlation, implied by Bravais in 1846,¹ received a great impetus from Galton in 1888, and, after its analysis in successive papers by Edgeworth, Pearson, and Yule, is now in general use. The more elementary processes of measurement by averages have been examined and extended by Galton, Venn, and Fechner, till the ideas of median and quartiles (used implicitly in Quetelet's method of fitting), mode, arithmetic average, dispersion, and mean and standard deviation, are common property with even the least advanced statisticians, and are coming into use in official statistics here and in the U.S.A. The most important inroad into official statistics has been made by index numbers. This method has grown very gradually, and has received impetus from many economists and statisticians; the most complete analysis of its mathematical basis is in the report of this section's Committee in 1887-1889.

In recent years progress in the development of theory has, indeed, been rapid, and a great number of important and thoroughly criticised methods are ready for use, and are, in fact, in constant use by biologists and botanists; but there has been remarkably little application to practical statistical problems. In the thirty years following the publication of Quetelet's 'Lettres,' attention was mainly given to establishing the constancy of great numbers and averages based thereon, an important but limited work, while the relation of the frequency of deviations to the law of error was regarded rather as a statistical curiosity. Professor Edgeworth's illustrations in 1885 of the importance of mathematical methods in testing the truth of practical deductions has as yet borne singularly little fruit. The attention of mathematical statisticians has been mainly directed to theory, and to actual measurement of anthropometrical and biological correlations; it is time that it was brought to bear on the criticism and analysis of existing industrial statistics. Something has been done by Yule and Hooker in England, by Norton in the U.S.A., and others, to test correlation and periodicity, and in other practical problems, but most of our statistics remain untested and their significance not analysed. The simple method of samples, illustrated below, for which all the materials have existed for at least twenty years, has (so far as I know) been completely ignored.

The region to which I am devoting particular attention is that where the theory of probability is invoked, not because there are not many other directions in which mathematical methods are useful, but because this is of the greatest importance and the least generally understood. All depends on a complete grasp of the nature of the measurement when we say, for example, that from certain data the most probable estimate of average wages is 24s.; it is as likely as not, however, to be as much as 4d. from this value: the standard deviation is 6d.; the chances are 10 to 1 against the average being over 24s. 8d., 100,000 to 1 against it being over 26s. This is the kind of statement to which calculations lead. The result may be briefly indicated as 24s. \pm 6d., when the 'standard deviation' is adopted as the measure of accuracy. In a normal curve of frequency about two-thirds of the area is within the standard deviation; the chance that a given observation should be within this distance of the true average is 2 : 1. The unit of measurement thus devised is most subtle and most complex. When it is applicable it gives the only complete measure of precision. When the initial

¹ Bravais' formula relates to the position of a point given by two co-ordinates, the sources of error of which are not independent. The term arising from this interdependence proved to be essentially the same as that reached by the later writers working from quite different standpoints,

difficulty of appreciating the nature of mathematical probability is overcome, a difficulty which rather grows than diminishes as one works at it, there still remains the greater task of deciding in what cases it can properly be applied and on the method of calculation. It has, in my opinion, often been used where it is not appropriate, where the chances of deviation are not those indicated by a normal curve, where it is a mere numerical value without involving the superstructure that makes the measurement of precision real. Thus it has sometimes been argued that if pn cases of a particular kind are found in n instances, then (without further analysis of the relation of the cases to the whole group) the

'statistical co-efficient' for the class is $p \pm \sqrt{\frac{p(1-p)}{n}}$, a deduction not

based on sound theory; if, in fact (here I follow Lexis), the deviation found from this formula is compared with that actually found from several observed values of p , the two do not in general coincide. In general, two lines of analysis are possible: we may find an empirical formula (with Professor Karl Pearson) which fits this class of observations, and by evaluating the constants determine an appropriate curve of frequency, and hence allot the chances of possible differences between our observation and the unknown true value; or we may accept Professor Edgeworth's analysis of the causes which would produce his generalised law of great numbers, and determine *à priori* or by experiment whether this universal law may be expected or is to be found in the case in question. It is to the latter method that my next remarks apply and on which the example I give depends. It can be shown¹ that if quantities are distributed according to almost any curve of frequency satisfying simple and common conditions, the average of successive groups of, say, 10, 20, 100 . . . n of these conform to a normal curve (the more and more closely as n is increased) whose standard deviation diminishes in inverse ratio to the number in each sample. My own practice is to take, first, a number of small samples (say of 4 or of 10 in each) and observe the curve of frequency for these; if there is a reasonable indication of the shape of the normal curve appearing, I calculate the 'standard deviation' for this grouping, say σ , and proceed with confidence to deduce that the average of a much larger sample, say of n , will have a normal curve of frequency, with deviation nearly $\sigma \sqrt{\frac{10}{n}}$, where 10 was the number

in the first group of samples. If we can apply this method—and for clearness I give an example immediately—we are able to give not only a numerical average, but a reasoned estimate for the real physical quantity of which the average is a local or temporary instance. It is the main weakness of statistical estimates, whether of those on a great scale supplied by English or foreign public departments or of more intensive inquiries by private investigation, that no measure of precision is given, and consequently that no determination can be made as to whether observed differences (in wages, in death-rates, in diet, in prices) are the accidents of observation or are really significant.

The example I have taken for illustrating the use of samples is worked rather roughly, but when we are calculating the chances of unknown deviations it seems unnecessary to go beyond the first decimal place. I took a copy of the 'Investor's Record' in which is given the yield per cent. to an investor at current prices on the basis of last year's dividends for 3,878 companies, and set to work to find the average of these percentages and the numbers giving various rates per cent. by sampling. Having numbered the list consecutively, I took the 'Nautical Almanac' and read down the last digits of one of the tables, in groups of four: if the number so read was over 3,878 I ignored it, if under (including such a number as 0063) I wrote down the corresponding interest from the table I was sampling. I thus secured equal chances for each of the 3,878 entries, and took one at a venture 400 times. It is necessary to make certain, in some such way as

¹ See Professor Edgeworth's paper in the Jubilee number of the Statistical Society, and subsequent papers there and elsewhere till that of June 1906,

this, that the chances are the same for all the items of the group to be sampled, and that the way they are taken is absolutely independent of their magnitude.

The forty averages of 10, so obtained, should by Professor Edgeworth's theory be grouped in a normal curve of error, and, in fact, they are, with modulus 1.096*l.* The average of the 400 is found to be 4.7435*l.*, with standard deviation .122*l.* The original items vary¹ from nil to 103*l.* The average, deduced from the samples, is thus known with practical certainty to be between 4*l.* 7*s.* and 5*l.*, and the chances are even that it is or is not between 4*l.* 13*s.* 3*d.* and 4*l.* 16*s.* 6*d.*² Actually, when the whole 3,878 were added together, the average proved to be 4*l.* 15*s.* 7*d.*

It is to be noticed that the precision of this and the following measurements does not depend in any way on the size of the group sampled, but only on its nature and on the number of samples taken, if the area of choice is co-extensive with the group. Here I have taken 2 in 19 as samples, but the results would apply equally well if my original list were extended a hundredfold or to any size; but then the task of verification would be prohibitive. If information were required as to the incomes, for example, of 1,000,000 persons, the labour of sampling to obtain results of given precision would be no greater than for 10,000 persons, except that precautions would need to be taken that each of the 1,000,000 had an equal chance of inclusion.

Having forecasted the average, I proceed to forecast the grouping. 7 per cent. are found with no dividend, 9 per cent. between 3*l.* and 3*l.* 10*s.*, and so on, as in the table on the next page. The precision of these measurements is found from themselves, and varies jointly as the square roots of the number in the whole sample and (nearly) of the fraction the class selected is of the whole. The precision can be made as great as we please, the probable and possible errors as little, by increasing the size of the sample. It is to be noticed that the deviations in the separate classes are not independent, since their sum is zero, and the problem is thus complicated. If an unlucky sample is taken for one group, there must be one or more bad samples for others. Where, in the table on the next page, no

¹ They are, in the list used, grouped according to the nature of the securities, Government, Municipal, Railways, Mines, &c., and the averages and standard deviations on successive pages differ materially. An artificial method of sampling is therefore necessary. This aggregation is very similar to that found in wages in different occupations and localities, and in many other practical examples.

² 400 samples taken at random from a list containing 3,878.

Average of 400, 4.7435*l.*

Modulus for 40 averages of 10, deduced from these averages, 1.096 = *c*, where

$$c = \sqrt{\frac{2\sum d^2}{n}}$$

Hence modulus for the average of 400 is $\frac{c}{\sqrt{40}} = .173*l.*$ 'Probable error' = .082*l.*

Standard deviation, .122*l.*

Hence average of all is as likely as not to be between 4.826*l.* and 4.661*l.*

The modulus for the average of 100 is .346, and, in fact, the deviations of the four sample averages of 100 taken from the average for 400 are +.06 +.20 -.27 +.003.

The 40 averages of 10 each conform fairly with a normal curve of error thus:—

Between Average	And Average	Actual	In Normal Curve	Between Average	And Average	Actual	In Normal Curve
+ <i>c</i>	+ $\frac{7}{5}c$	3	2.2	+ $\frac{3}{5}c$	- $\frac{1}{5}c$	8	7.6
+ $\frac{3}{5}c$	+ <i>c</i>	5	4.8	- <i>c</i>	- $\frac{3}{5}c$	7	4.8
+ $\frac{1}{5}c$	+ $\frac{3}{5}c$	7	7.6	- $\frac{7}{5}c$	- <i>c</i>	3	2.2
- $\frac{1}{5}c$	+ $\frac{1}{5}c$	6	8.9	And 1 instance at + 2 <i>c</i> .			

When the curve of frequency is normal with standard deviation σ , the chance that any particular case shall differ from the central value by as much as σ is .317; 2*σ*, .046; 3*σ*, .0027.

standard deviation is given it is considered that the class is too small for any good forecast.¹

We are thus able to forecast that about 7 per cent. of the investments yield nil, 27 per cent. between 3*l.* and 4*l.*, 29 per cent. between 4*l.* and 5*l.*, 15 per cent. between 5*l.* and 6*l.*, and the remaining 20 per cent. yield over 6*l.* per 100*l.*

While the above was in the press I tabulated the whole group, and entered the numbers in the column 'Actual Distribution' in the proof. It is seen that the agreement between prediction and fact is most satisfactory except in the case of the group above 8*l.*²

The average yield calculated must not be confused with the average return to capital invested; it is simply the average of the rates tabulated, taking all the companies as of equal importance.

¹ *Distribution of Samples.*

—	1st 100	2nd 100	3rd 100	4th 100	Forecast		Actual Distribu- tion
					Average per cent.	Standard Deviation	
<i>Dividend:</i>							
Nil	6	5	8	9	7	± 1.27	6.0
£ s. d.							
1 0 0 to 2 19 9	3	0	3	0	1½	—	1.5
3 0 0 „ 3 9 9	10	10	7	10	9¼	± 1.46	8.4
3 10 0 „ 3 19 9	24	13	22	12	17¾	± 1.90	18.8
4 0 0 „ 4 9 9	14	14	16	20	16	± 1.83	17.3
4 10 0 „ 4 19 9	11	16	12	14	13	± 1.68	13.8
5 0 0 „ 5 19 9	13	18	16	13	15	± 1.78	17.7
6 0 0 „ 7 19 9	9	16	9	14	12	± 1.63	10.8
8 0 0 „ 10 19 9	8	8	7	6	7¼	± 1.29	3.8
Above 11 0 0	2	0	0	2	1	—	1.9
<i>Aliter:</i>	100	100	100	100			100
£ s. d.							
Below 3 0 0	9	5	11	9	8½	± 1.4	7.5
3 0 0 to 3 19 9	34	23	29	22	27	± 2.2	27.2
4 0 0 „ 4 19 9	25	30	28	34	29¼	± 2.3	31.1
5 0 0 „ 5 19 9	13	18	16	13	15	± 1.78	17.7
6 0 0 „ 7 19 9	9	16	9	14	12	± 1.63	10.8
Above 8 0 0	10	8	7	8	8¼	± 1.4	5.7
	100	100	100	100			100

The standard deviation is thus calculated: If m examples are found in 400 samples, the deduced frequency for the class is $\frac{m}{400} = p$, with standard deviation for the percentage found in class approximately $100 \sqrt{\frac{p(1-p)}{400}}$.

The numbers in the 2nd to the 5th columns belong, row by row, to normal curves, with the centre given in the 6th and twice the standard deviation given in the 7th column. Thus, in the 3rd row, the average is 9¼, the standard deviation for 100 is 2×1.46 (1.46 being the deviation for the average of the four columns), and the four cases (10, 10, 7, 9) are all within the standard deviation.

² Among the 3,878 cases there are 27 yielding exactly 10*l.* per cent.; of these 8 appeared in my sample of 400. There are in all 149 yielding from 8*l.* to 10*l.* 19*s.* 9*d.*; of these 29 appeared in my sample. The chance that so many as 29 should come in perfectly random sampling is only .0008, say the chance of drawing two named cards from a pack of 52. I cannot discover anything in my process to lead to such a result

The method of sampling is, of course, only one of many instances of the application of the theory of probability to statistics. I have taken it at length because the method is so persistently neglected, and even when it is used the test of precision is ignored. We are thus throwing aside a very powerful weapon of research. It is frequently impossible to cover a whole area, as the Census does, or as Mr. Rowntree here and Mr. Booth in London successfully accomplished, but it is not necessary. We can obtain as good results as we please by sampling, and very often quite small samples are enough; the only difficulty is to ensure that every person or thing has the same chance of inclusion in the investigation.

The use of such methods must remain for some time in the hands of specialists for several reasons. The theory is still in the making; no general rules can be laid down, and considerable judgment is needed as to how far a particular theory is applicable to a given problem. There is still some difference of opinion as to the best method of grounding the theory, and there is not complete agreement as to the meaning to be attached to the technical terms or as to the best terms to be used. Again, the observations we are able to make are so few and so rough that special skill is required to handle them; the worse the tools, the better must be the workman. So far, too, there is dearth of raw material for educative or laboratory work, though suitable groups of statistics are now accumulating rapidly. These conditions strengthen, rather than weaken, my demand for an adequate supply of specialists, and for the proper preparation of those whose duty it will be to handle statistics in a few years' time, when the methods will be more perfect. On the other hand, they support the general practice of the non-inclusion of the more advanced mathematical methods in undergraduate courses; but I could wish that the line were not drawn quite so low.

The use of the methods I have indicated can be illustrated from almost any branch of statistical inquiry. In dealing with wages we have to determine whether the samples we have are sufficient. In studying trade records we need to know the precision of our index numbers, the theory of weighted averages, and the measurement of trend and of fluctuations. In questions of income and income-tax we have to consider what help Pareto's law of graduation can give. In sociological and anthropometrical investigations, whether we are considering the malnutrition of children, or the alleged deterioration of national physique, or the birth-rate, or the employment of women, we have again and again to take mathematical means for describing the groups or estimating the precision of the averages and the significance of observed differences. In most cases of cause and effect, and in general in testing the interdependence of phenomena, we have to use the mathematical measure of correlation, a subject whose importance demands much more than the brief mention here given.

For illustration of the immense practical importance of such methods I offer a brief analysis of the most important and pressing of modern economic problems, showing in what respects mathematical statistics are needed. What do we actually know of, and how should the nation deal with, the classes who do not fit in with the ordinary and normal economic life of society—who do not, as a fact, attain any reasonable standard of life in our *régime* of free competition: the sweated, the casual labourer, the frequently unemployed, the permanently unemployed, and their forerunner, the underfed and uneducated child?

As economists and statisticians we are not concerned with palliatives or methods of expediency, but with a correct knowledge and true diagnosis of the extent of the evils, on which can be built reasoned and permanent remedies.

As is generally the case, our information as to the facts is hopelessly incomplete. There is no agreement as to scientific classification, no complete estimate of numbers; nothing but most limited records, supplemented by ill-informed guesswork. This is the case at the present moment, when public attention has been focussed on these questions for some time. Still less do we know anything about conditions thirty, twenty, or even ten years ago. In these circumstances

we cannot say whether the very serious conditions which are obvious at present are better or worse than those of previous decades; whether, for example, the number of able-bodied men who are earning less than 40% per annum has increased or decreased, absolutely or in proportion to the population. Remedies depend not only in extent, but in kind, on the numbers to be dealt with. Private resources may be sufficient to re-establish on a sound economic basis a small number of men who have been unable to weather an economic storm, but quite other means are necessary if a large class has lost the means or habit of earning a livelihood. Similar remarks apply to all the classes to whom I am referring. Till we know the facts we cannot prescribe the remedies, and it is during this period of trade activity that we have the leisure to gather the facts.

To learn the actual economic condition of all the 40,000,000 persons of the United Kingdom, or even of those who are not obviously above any possible poverty line, seems at first sight an impossible task; and so indeed it is, but only because of general apathy as to the subject. We must, therefore, proceed by some method of samples. Before we can get sound information from samples we must have a method of numbering or classification by persons or by districts. If we had a definite system of registration and identification, as in Germany, it would be easy to choose, say, 1 in 100 or 1 in 1,000 at random from among all the persons whose record satisfied certain conditions, and then to investigate more carefully the history and circumstances of those chosen. A similar method could be applied to any particular district. There is no need to make a house-to-house visitation to learn the conditions of a district; it is sufficient to enumerate the houses, to choose a certain proportion at random, and investigate carefully the status of their inhabitants. But the area of choice must be coincident with the area to be investigated.

When we have the sample, and have tested its precision by internal evidence, there are still difficulties of classification; but these can be overcome without mathematical analysis.

The economic analysis of these problems is constantly in need of help from statistics. What is the cause of, and what the remedy for, the existence of a large body of able-bodied persons frequently out of work or working for a wage below any reasonable standard? The least acquaintance with economic theory will lead us to deny any permanent absence of demand for a large body of existing labour in normal conditions; the difficulty must lie in the unfitness of the supply. The root cause economically is the fact that these persons are not fit for any of the work which society as an organisation needs. The unfitness may arise from the permanent loss of the trade to which the persons belonged; or to mental or physical deterioration following a bad spell of periodic unemployment (a phenomenon to which I return); or may be, and is, I think, more likely to be due to an absence of preparation for any of the employments which need more labour. In fact, it appears that at present in England the demand for labour is not sufficiently definite, and the supply too badly organised, to obtain equilibrium.

In a progressive or changing society new trades are continually growing, old trades altering their character or dying out. The latter process does not necessarily, nor, I think, generally, mean the throwing out of work of existing employees; it rather means the checking the demand for recruits who should enter the newer trades, which in normal circumstances attract them with higher real wages. There is, however, no information available by which an intelligent artisan can decide into what occupation to put his son. A good deal could be done by mathematical and actuarial work, based on the successive occupational Censuses (if these could be improved), to forecast what trades were relatively overcrowded. More could be done by a very careful organisation of technical schools, directed to educating the young for the trades of the immediate future. At present the choice of a trade is too much a matter of chance, decided by the immediate vacancy in the neighbourhood, or by an ignorant observation of the temporary prosperity of a particular industry. For example, superficial observation suggests that too many lads have entered the building trades in the last twenty years; but, as usual, our sources of information break down when this is examined.

It is true that, even at present, new trades and growing trades are very rapidly supplied. Skilled labour as a whole is very fluid; witness the manufacture of cycles in the eighties and nineties, the more recent motor-car industry, the great increase in the number of coal miners. On the other hand, the unemployment statistics in years of good trade show that the process of transmutation is not sufficiently rapid. The possibility of improvement lies in regulating the supply. An even more serious difficulty is that of moving from one grade to another. We are very ignorant on the subject, but it is commonly alleged that the son of an unskilled workman in general must also be unskilled. The father's wages being low, the lad must get to work at once, at the first thing that opens. There is a permanent demand for errand and messenger boys, and generally for quite unskilled labour at the bottom of an industry, which if not checked throws a great many young men adrift to begin the world at eighteen in total ignorance of any useful occupation. There is, therefore, a tendency for a permanent oversupply of the unskilled relative to the skilled. It is not known whether in modern industry the proportions of skilled, partly skilled, and unskilled have changed or not. I have not found any significant alteration in such inquiries as I have been able to make. But this proportion is not fixed by any natural law. A deficit of unskilled would soon be supplied by machinery; processes are rapidly adapted to the labour supply. The labour market could readily absorb a greater supply of skilled men, if their skill was that in demand in the growing trades. If we want to check the growth of ignorant and unadaptable labour, we must save the boys of thirteen and fourteen from entering occupations that offer no future, and provide them with that knowledge and technique which industry will need five years later. The reason why a not unwilling worker cannot find an employer is not the want of sufficient capital, but the uselessness of the workman to society. So far we can get by *à priori* reasoning; whether the facts are correctly stated can only be decided by careful inquiry, applying the mathematical methods of sampling, averaging, and grading. A purely arithmetical inquiry, as that conducted at the London Docks by Mr. C. Booth, and at Liverpool by Miss E. F. Rathbone and Mr. G. H. Wood, will, however, throw a flood of light on such a question as to how many men are wanted, and how many in fact are present, in a trade. We may also hope to learn a great deal from a study of the information collected by the various relief agencies in the recent period of unemployment.

The question of periodic unemployment (as opposed to chronic want of work) is easier to handle and is better understood. It is, however, in need of very careful investigation; and I may remark that the most recent inquiry put to me as to mathematical processes related to the question of forecasting the turning-point towards better or worse trade. The cycle of commercial credit, which is very intimately connected with employment, is best studied by index numbers of prices and of quantity, and the most advanced mathematical work done by Section F¹ related to these numbers. The more the nature of a crisis is understood, the better it can be discounted and its worst effects mitigated, and there is some evidence that this is now done. When the recurring wave of unemployment is sufficiently well known, proper rates of insurance for want of work can be established, and the very extensive insurance in this direction by trade unions and other bodies can be put on a safer basis. It is a curious point, and one little noticed, that in the high tide of trade work is plentiful and wages high; but prices are also high, and therefore the purchasing power of a sovereign low. This is the time to save, whether privately or in a society; for when the tide falls there is both more leisure to spend and the purchasing power of money is greater. Those whose occupation is affected by the commercial cycle have their salvation in their own hands.

There remain those who are physically or mentally unfit for work, who must always be a burden on their more fortunate fellows, and in considering them we pass out of the region of economics. But in this, as in other sociological questions, we still need statistics—perhaps most those methods of measurement we associate

¹ Report of Committee on Variations in the Monetary Standard, 1888-1890.

with Galton's name—to enable us to understand the magnitude and nature of the burden to be supported.

Again I would urge that in regard to all these questions we are in a condition of great ignorance. If the numbers of unemployed or unfit are increasing relatively to the population at large, the position is very serious and heroic remedies are wanted; but if they are diminishing, while we lament the present evil, we may be hopeful as to the future. What light do statistics, mathematical or otherwise, throw on this question? We know that the wages of regular workers have increased steadily for many decades, whether measured in cash or in purchasing power, and that hours of labour have diminished progressively. The consumption of necessary commodities and of common luxuries has increased more rapidly than the population. Working-class savings and investments have grown enormously. What evidence we have indicates that aggregate wages and aggregate national income have increased at nearly the same rate. Unemployment, so far as it is registered, has, period for period, been at nearly the same level for forty years, except that the years of good employment were specially numerous in the nineties. But this is only one side—the visible side—of the picture. For the permanently unemployed and unfit our only records are the singularly inadequate and imperfect statistics of pauperism. We have nothing to go on but guesses as to the real extent of poverty. We cannot recover records for previous years, and statistical science must remain powerless where there are no data. We are not taking any steps as yet to learn our existing condition in any complete way, though the work done in intensive inquiries would have been sufficient, if directed over the whole field, to have given us an adequate sample.

It is because of the immediate and pressing need of information before we commit ourselves to dangerous remedies on an erroneous diagnosis, that I have spent my allotted time in pressing the importance of scientific method in statistical research.

The following Report and Papers were read:—

1. *Third Report on the Accuracy and Comparability of British and Foreign Statistics of International Trade.*—See Reports, p. 339.

2. *Theory of Distribution.* By Professor F. Y. EDGEWORTH, LL.D.

That the shares of the national dividend are determined by a complicated play of supply and demand (with implicated propositions as to 'marginal' value); that the process of production and distribution has the character of a flow; that certain factors of production are not only attracted from one destination to another, but also called into existence by the prospect of remuneration—these leading principles are re-stated with dialectical reference to contemporary writings.

3. *The Inhabited House Duty as a Graduated Tax.*
By JAMES BONAR, M.A., LL.D.

The tax dates from Adam Smith and Lord North. It is unlike the income-tax in steadiness, stringency, inevitableness, and independence of 'taxation at the sources.' It is unlike a rate or a land tax in its uniformity within Great Britain. It produces to the revenue about two millions a year, raised (a) from dwelling-houses on a scale of three steps, 3*d.*, 6*d.*, and 9*d.* in the £ of annual value, and (b) from residential shops, farmhouses, hotels, &c., on a scale of three smaller steps, 2*d.*, 4*d.*, and 6*d.* The imperfections of the graduation are most striking in the higher steps, but quite as real in the lower. The resulting hardships are not to be explained away by shifting, although that, too, is real.

It is possible to suggest a graduation which should begin from the same

point as at present (3*d.* for 20*l.*) and proceed by steps of one penny's difference to 1*s.*, and by a greater leap to 1*s.* 6*d.*, for the most valuable dwellings, the residential shops, &c., being treated in a similar manner, but (as now) with more indulgence. A rough calculation shows that the same amount as at present could thus be secured by the Chancellor of the Exchequer on a better graduated scale than the existing one, and therefore at the cost of less suffering to the community at large.

FRIDAY, AUGUST 3.

The following Papers were read:—

1. *The Influence of the Rate of Interest on Prices.*
By Professor WICKSELL, Ph.D.

1. The rate of interest influences prices not by its absolute, but by its relative, height, in proportion to the existing rate of profit on capital, *prices being forced up when the rate of interest on money is low in proportion to average profit, and pressed down in the opposite case.*

2. A difference between the two rates (of interest and of profit) generally occurs, not by the rate of profit remaining constant and the interest on money spontaneously rising or sinking, but, on the contrary, by the inevitable alterations in the rate of profit itself, which are followed, but not very rapidly, by similar changes in the rate of interest, so as to give the impression that the rise or fall of prices is due to a similar movement in the rate of interest, whereas in reality it is caused by the interest of money not rising or falling fast enough in comparison with the existing rate of profit.

3. Yet under present circumstances, so long as metallic money remains the standard of value and free coinage of gold is allowed, the regulation of prices by the rate of interest has a very limited range, the banks being forced by the reduction or the increase of their reserves to heighten or lower their discount, as the case may be, so that the production of gold always takes the lead in the long run in determining the average level of prices.

4. If this obstacle be removed, however, by the free coinage of gold being stopped, as that of silver has been stopped, an appropriate manipulation of the rate of interest by common action of the leading banks of the world would be the means of keeping the general level of prices, and consequently 'the value of money,' practically constant.

2. *The Specie Reserve of the United Kingdom.*
By R. H. INGLIS PALGRAVE, F.R.S.

The question as to the amount of the specie reserves which the banks of the United Kingdom should maintain is one which comes forward for consideration continually. In a recent address Mr. Alfred Clayton Cole, one of the best-known directors of the Bank of England, has again called attention to the subject. In this public utterance Mr. Cole declared that, in respect to the reserve, it was no business of the Bank of England during any time of crisis to take care of the other banks of the country. All the Bank of England was called on to do was to take care of itself. The subject has since been discussed on several occasions by leading London Bankers, the Governor of the Bank, the Chancellor of the Exchequer, Lord Goschen, and others. A general opinion has been expressed that the Specie Reserves require to be strengthened.

If this opinion expressed by Mr. Cole is to be the guiding maxim of the Bank of England in future, it behoves the other banks to take some steps towards ensuring their own safety. In doing this there are three main courses which might be followed:—

1. For the banks to increase their balances at the Bank of England.
2. To establish a separate reserve of their own which might be kept at the

Bank of England, but need not necessarily be included in the weekly published statement of accounts.

3. For each bank to increase the stock of specie which it holds in reserve. Such a course, which has sometimes been suggested, might be useful; but the carrying it out would not have the effect of strengthening the central reserve, which should be visible to all the world.

With respect to the first proposal—Should the existing bankers' balances be increased?—this merely means increasing the amount which the Bank can lend out in competition with the other banks. The second proposal appears more closely to meet what is wanted.

Meanwhile, the reserve of the Bank itself, which is also the ultimate reserve of every bank in the United Kingdom, has gone through a considerable change in its composition since the year 1844, when the present Bank Act came into force. Those of the notes entered in the weekly account as 'issued,' which are not in the hands of the public, remain in the banking department, and form the reserve. Against part of the notes issued by the Bank, securities are held, and specie is held against the remainder. The amount of the issue against securities was originally 14,000,000*l.*, it being assumed that the business of the country would always require that amount to be in circulation. The Bank Act of 1844, by which this arrangement was settled, also empowered the Bank to issue further amounts against securities to the extent of two-thirds of the country note circulation of England and Wales which might be withdrawn. Under this provision 4,450,000*l.* has been added to the amount issued against securities, the total of which is now 18,450,000*l.*

This brief statement shows the position of the banking reserve of the country at the present time. The Bank of England, by raising or lowering its rate, influences the amount of the reserve. This in a general way meets the difficulty, but it sometimes happens that an import of specie has to be made to meet a special requirement at an extra charge higher than the Market Rate, but we must remember that every rise in the rate of discount above that of the countries which surround us has an influence on the activity of our business, to which cheap capital is as essential as the cheapness of other elements of production.

In this country we have not followed the policy of other countries, which have of recent years made great efforts to increase their reserves.

The following figures will show what some of the leading banks of the world have done during the last few years.

The specie at the Bank of France was in 1877 81,088,000*l.*, being, gold, 46,544,000*l.*, and silver, 34,544,000*l.*; in 1905 it was 157,420,000*l.*: gold, 114,572,000*l.*, silver, 42,848,000*l.*

The specie of the Bank of Germany was in 1877 25,030,000*l.*, and in 1905 40,179,000*l.*, being, gold, 29,819,000*l.*, and silver, 10,360,000*l.*

The National Banks of New York held: In 1876, specie, 3,600,000*l.*; legal tenders, 8,500,000*l.*—12,100,000*l.* in all. In 1905, specie, 36,000,000*l.*, legal tenders, 15,000,000*l.*—51,000,000*l.* in all.

The average reserve of the Bank of England was: In 1876, 15,962,000*l.*; and in 1905, 25,307,000*l.*

The figures of the London Bankers' Clearing House were: In 1868, 3,425,185,000*l.*; and in 1904, 10,564,197,000*l.* These figures are only quoted as indications of a greater activity in business.

Meanwhile the balances to the credit of the banks of the United Kingdom, not including the Bank of England, were: In 1894, in round figures, 625,000,000*l.*; and in 1905, 800,000,000*l.*

A general levy of 1 per cent. on the deposits of the banks of the United Kingdom would, in round figures, amount to 8,000,000*l.* Supposing this suggestion to be accepted, much more would have to be done before such an arrangement could be brought into working order. A committee of representative men would have to be formed, and arrangements made with the Bank of England as to the custody of the specie and as to the course to be followed by them in any time of pressure.

The reserves of the banks of the country are already very large, and one hesitates to suggest an addition to them. Yet if a special reserve is to be formed the difficulty will have to be faced.

It may assist us to form some idea as to what might be required if we remember that the preparations made in other countries against such difficulties show what they think necessary, and the position we hold renders it advisable that we should take similar precautions. We are at present the clearing house of the world. Can we expect to retain this position unless we make an effort to show that we can without difficulty, and without having to make any special effort, honour the demands which at any time may be made on us?

3. *The Gold Reserve.* By D. DRUMMOND-FRASER.

England has at last realised the national importance of the strengthening of her gold reserve. The whole thinking community has become alive to the vital necessity of acquiring and maintaining an additional central stock of gold.

The practical difficulty in solving the problem is: who is to bear the cost?

English Joint-Stock Banks.

Why should the joint-stock banks bear the cost? *Firstly*, they increased their balances at the Bank of England by over five millions in 1890, and these balances form practically the entire banking reserve held at the Bank of England. *Secondly*, they increased their holding of Bank of England notes. The effect of these two has been the strengthening of the percentage of cash resources, together with the reduction of the percentage of loan and discount to the deposit liabilities. Does not this record justify the restoration of the right of issue to the joint-stock banks of notes of 1*l.* and upwards, *plus* the provision of a second central gold reserve?

Bank of England.

On the one hand the present system often leads to an accumulation of gold, which induces a low Bank rate; while on the other hand the Bank of England's stock of gold is liable to be depleted, which causes higher rates. Sixty years ago the money market was controlled by the Bank of England; now it is controlled by the joint-stock banks. A revision of the present arrangement between the Bank of England and the Treasury is necessary so that the Government debt be repaid in gold. This would also raise the question of an emergency issue over and above the gold bullion on the German or even the Scotch elastic system.

The Savings Banks.

How is the Chancellor of the Exchequer going to make good the deficiency of 11,000,000*l.* (in consequence of the drop in Consols) which is requisite for the putting in order of his balance-sheet?

The practical steps necessary for the strengthening of the gold reserve are:—

The Chancellor of the Exchequer should accumulate a gold reserve of 1,000,000*l.* per annum for ten years. The Bank of England should replace at the expense of the Government 4,450,000*l.* securities by gold, and arrange to hold gold in place of the Government debt. And an arrangement should be made with the large joint-stock banks for the issue of 1*l.* notes, coupled with the provision of an effective second central stock of gold.

4. *Industrial Organisation in the Woollen and Worsted Industries of Yorkshire.* By Professor J. H. CLAPHAM, M.A.

Technical distinction between the woollen and worsted branches of the industry. The chief economic distinctions are (1) the greater size of the normal business concern in the worsted branch, and (2) the normal subdivision of the

worsted manufacture into combing, spinning, and weaving as opposed to the combination of all processes in each firm in the woollen industry. Aim of the paper to throw light on the causes of these differences.

The causes are partly technical, partly economic; some are of old standing, some are the outcome of recent developments. In the first place, at the time of the industrial revolution the worsted trade in Yorkshire was younger and more adaptable than the woollen trade; large mills grew up more generally and rapidly.

Worsted spinning was always an 'export' trade in Yorkshire, and recent developments have accentuated this characteristic.

Technical considerations largely account for the establishment of combing as a separate trade; here again recent developments have stimulated an existing tendency.

Separation of spinning and weaving in worsted encouraged by (1) the extensive use of yarns other than worsted, and (2) the great variety of fabrics manufactured.

The late survival of the master clothier and the hand-loom, in part responsible for the present organisation of the woollen trade.

An important technical consideration in the case of the woollen industry, which tends to preserve the present type of organisation, is the absolute necessity that the manufacturer should control the spinning of his yarn. (This being in some ways desirable in both branches, the worsted trade suffers somewhat from the existing sub-division.)

'Infection' from the cotton trade is at times alleged as the cause of the sub-division of the worsted trade; some slight force in this.

The great variety of processes in the typical woollen mill and the limitations of the market partly explain the relatively small size of the mills.

The partial supersession of woollen by worsted since the 'seventies helps to explain the present organisation of the former industry.

5. *Cheap Railway Tickets for Workmen in Belgium.* By Professor E. MAHAIM, LL.D.

During the last ten years the weekly 'abonnements' for workmen have increased so rapidly that it is probable that Belgium will shortly become, for some kinds of labour, strictly one market, *i.e.*, distances will have practically no effect on the price of labour.

The origin of especially cheap weekly tickets for workmen goes back to 1869. Until 1888 their number increased but slowly. In that year it was eleven millions. It doubled between 1889 and 1895, reaching twenty-one millions in the latter year. Since 1895 the increase has been still more rapid: in 1905 more than fifty-three million such tickets were issued. It is estimated that about 120,000 workmen, *i.e.*, one-sixth of the total industrial population, use these tickets on the State and companies' railways.

The cheapness of the fares may be measured by the fact that the weekly ticket for six daily return journeys costs less than one ordinary third-class return ticket. The average length of journey was in 1904 seventeen and a quarter kilometres, or about eleven miles, and the average ticket cost twelve centimes, or less than seven-tenths of a centime per kilometre.

Now let us consider the main effects of this phenomenon.

A. As direct economical effect, the double purpose aimed at is really attained: (1) To give sufficient and cheap labour to employers; (2) to give more opportunities to the labourers for finding work. Many trades or businesses in towns and large villages could not have been started, and many Flanders labourers or agricultural hands would not have had industrial work—and wages—had it not been for the cheap tickets. The indirect consequences are obvious: (1) Relative equalisation of wages in both senses—those in trades' places lowering and those in agricultural districts increasing; (2) The great cheapness of labour in the whole country—a characteristic of Belgium—being maintained; (3) The competition between employers bearing more on other elements of cost of production than labour,

B. As regards the rush from country to town, if the cheap trains have not stopped it, they have undoubtedly moderated it. Lower rents and other advantages (gardens with vegetables) have retained in the country people who would have had to leave had the railway facilities not been available.

It is one of the reasons why, on the whole, rents for workmen's houses in towns are relatively low in Belgium.

Cheaper building ground and materials determine workmen to build their homes in the country. Many amongst those who regularly travel to and fro own their homes. Some combine even some little rural enterprise with industrial labour.

At the same time rents in the country must have been maintained at a level higher than that which would have prevailed had it not been for the cheap trains. But it should be remarked that in the villages the law of supply and demand acts less than in greater markets.

C. The moral and political aspects of the phenomenon remain to be considered. (1) The bulk of those who travel to and fro every day avoid the promiscuous mingling of the sexes so often found in the overcrowded town houses, but a great part of those who travel once weekly have to use town lodging-houses, where evils of promiscuity are numerous. (2) Daily or weekly travel enlarges their mental capacity and education. (3) The workmen's trains are well-used opportunities for Socialists' propoganda, so far that in Parliament Mr. Vandervelde once greeted the Minister of Railways as the greatest Socialist propogandist of Belgium.

On the whole it may be said that the cheap workmen's trains are powerful agents, which tend to the mobility of labour, to equalise competition, and to increase the social density in the commonwealth.

MONDAY, AUGUST 6.

The following Papers were read:—

1. *Some Notes on Railway Cost Statistics.* By R. L. WEDGWOOD.

The problem of devising an organised system of statistics for indicating fluctuations not only in general costs of railway working but also in the more detailed costs of special processes, and for co-ordinating the two, is probably one of the most important which English railways have to face at the present time.

In a large organisation such as a modern railway it is impossible to keep an adequate control over all the ramifications of the business without some system of summarising and reporting the work done and costs incurred by the various departments into which the operations of the railway are split up. This is admitted on all hands, but there is some dispute as to the point to which this process should be carried.

Experiments in the direction of establishing a complete system of statistics have been made within recent years on the North Eastern Railway. These arose from recognition of the necessity of increasing the train load and of effecting other economies; a continuous record of the progress made, compiled on scientific principles, was held to be essential. The record of train mileage run and tonnage hauled gave no such information, and no record of train load in tons or in any other trustworthy form could be obtained without the ascertainment of the distance over which the tonnage required to be hauled. It was accordingly decided to ascertain these particulars, the composite figure arrived at being known as ton mileage. This figure, taken in conjunction with train mileage, gives the train load in terms of tons.

Further experiments along the same lines have led to the ascertainment of wagon miles, both loaded and empty, and, as a compendious test of the efficiency of work done in conducting transportation, have evolved the figures ton-miles per engine hour, and wagon-miles per engine hour,

The engine hour is taken as the unit of cost so far as the conduct of transportation is concerned. This unit varies, however, in actual cost, and this points to the necessity of organising locomotive cost statistics in a form to record fluctuations in actual costs per engine hour, and generally to organise cost statistics in various departments so as to co-ordinate with 'operating' cost statistics, as at present worked out. This branch of the question is still in an experimental state.

Theoretically, the question of railway statistics is complicated by the fact that there is no single unit of product—the ton-mile and the passenger-mile cannot be combined. The costs of passenger and freight working can theoretically be worked out separately, but it is not yet certain if this will have practical value.

Certain costs, however, can be taken separately for the two branches, and, in particular, train costs. As regards passenger working, little use has been made of this, but this is due—

(1) To the impossibility of ascertaining the product in terms of passenger miles, owing to the wide use of contract tickets.

(2) To the control exercised over the working by non-economic causes, the necessities of public service, &c.

(3) To the more speculative character of the business.

In the case of freight working, however, the fact that freight train costs can be taken out separately enables us, as described, to work out the foundation of a fairly complete system of statistical analysis. This has been found to be of great practical value, and to point the way to fresh improvements.

2. *Some Principles of Freight-traffic Working.* By W. T. STEPHENSON, B.A.

The growing demands of 'Labour,' the increased cost of coal and materials, and the increase in rates and taxes, which occurred during the last decade so increased the cost of conducting transportation as to seriously lower railway profits. In consequence, great efforts have had to be made to work traffic in a more economical manner. The investigations into the cost of conducting certain operations have brought to the front some principles of freight-traffic working which, when applied, have proved very effective in reducing the cost of operating the traffic.

The first principle is to work the traffic in large train-loads. By increasing the train-load the number of trains on the line is proportionately decreased. This tends to prevent detention on the road by making it easier to obtain clear times for the train. Again, exactly the same staff is required to work a through train, whether it has a small or a large number of wagons on it. On the other hand, it is quite true that the powerful locomotive capable of working a large load costs more to build and consumes more coal, oil, and water per mile run than the smaller engine. However, neither the constructional cost nor the working cost increases proportionately to the increase in capacity.

Growth, however, in gross train-load is only a very small move forward. The growth in net or revenue-earning train-load is what matters most. The use of powerful engines can do no more than increase this in proportion to the increased capacity of the engines. Improved loading of the wagons is quite as important a matter as increased gross train-load. By increasing the load of a wagon we reduce the ratio of dead-weight to revenue-earning weight. When it is borne in mind that the dead-weight hauled is on the average more than double the paying load, the importance of loading the traffic into a smaller number of wagons becomes very clear. Improved wagon loading also has the advantage of reducing the number of wagons required to deal with the traffic, and so reducing the capital it is necessary to invest in wagon stock.

With goods traffic the means adopted to improve wagon load are 'intercepting' and 'organised transhipping.' The former has as its objective the saving of haulage of light-loaded wagons by combining the loads of two or

more wagons for the same destination. It is particularly applicable to the transfer of traffic between two or more railway companies. Transshipping has as its object the handling of small consignments in as few wagons as possible. The small consignments for several destinations are loaded together in one wagon to some point in the direction of the said destinations, with the intention of being distributed from that point. Transshipping has always been recognised as necessary; the great step forward has been systematising it.

Improved wagon-loads could not, however, be obtained for mineral traffic in this way. As a rule, mineral wagons when loaded are full, and more cannot be got into them. To obtain larger loads, therefore, it is necessary to provide wagons of higher capacity. As mineral consignments can be got in large quantities, there is no difficulty in this respect in using wagons of larger capacity. The great economy of large-capacity wagons lies in the considerable reduction in the ratio of dead-weight to paying load, and in the shorter siding space required to stand the same quantity of traffic. As in the latter, in some cases, the reduction is as much as 40 per cent., its value is easily realised.

The value of larger wagons is not, however, limited to mineral traffic. There has always been a quantity of goods traffic for which large-capacity wagons would be serviceable, and the application of 'intercepting' and 'organised transshipping' has rendered a much more extended use possible.

3. *The Distribution of Population by Facilities of Rapid Transit.*

By LYNDEN MACASSEY, M.A., LL.D.

Under modern urban conditions, the prevalent and well-recognised economic and social forces lead to the aggregation of population into dense communities, of which London furnishes an extreme example. External immigration is generally directed to the central districts, and in conjunction with natural increase of population produces overcrowding with its attendant evils. Facilities for locomotion furnish the only practicable countervailing in rendering practicable and inducing a tendency towards suburban residence. Rapid transit—an American expression—is usually used to denote the facilities for urban and suburban locomotion provided by mechanical traction. Such facilities in great cities mainly consist of surface, elevated, and underground railways and tramways, and of street conveyances. Each extension and improvement of such facilities shows itself in distribution of the population of a city outward from the centre and development of suburbs, but the economic effect, the area of influence and the section of the population served, depends on the 'quality' of the facilities provided. The object of the paper, therefore, was to show by reference to English, American, and Continental experience the comparative extent to, and manner in, which in modern cities the distribution of population has been so affected.

4. *Lead Mining in Yorkshire.* By JAMES BACKHOUSE.

The general subject of lead mining in the North of England has been somewhat exhaustively dealt with, both mineralogically and geologically, by various writers, but hitherto the historical side of the question for any given county has not been systematically treated.

In 1863 the late Mr. Thomas Sopwith, F.R.S., read an admirable paper before this Association on the local manufacture of lead, copper, zinc, antimony, &c. Tracing as he did the general history of the mining of those metals in the various districts, especially of the North of England, it was obviously impossible to particularise on any one metal, but as a general epitome the article was absolutely reliable.

In 1848 a paper was read before the Yorkshire Philosophical Society, and published in their Transactions, entitled 'Thoughts on Ancient Metallurgy and Mining in Brigantia and other parts of Britain,' while giving an excellent

summary of our knowledge of early mining in the country, does not attempt to define any special area or set of mines. More recently Mr. Stephen Eddy has written upon the 'Lead Mining Districts of Yorkshire,' mostly from a geological standpoint, and where statistics are given they are of great value.

For many years Yorkshire held a most important place as a lead-producing district, and it is probable that during the palmy days of the industry at least three thousand persons were employed, directly or indirectly, in lead mining in the county. To-day there are probably not more than twenty-five all told!

It is clearly proved that lead has been mined for many centuries in Yorkshire, not only in Roman, but in Brigantean times. Pigs of lead can be shown, found in Yorkshire, bearing the Roman impress. In the 'baile,' or 'bole-hills,' and probably in one or two drifts and shafts, we have evidence of Brigantean working; some of it possibly dating back earlier than the Roman invasion.

In many districts tradition points to Roman mining, but evidence is not forthcoming to show whether these conquerors actually mined it themselves or whether they begged, borrowed, or stole it from the subjugated tribes.

From those times, however, through what we may call the early documentary period, lead was mined more or less systematically in Yorkshire, often in large quantities, and there can be no doubt also to large profit.

But we have to deal especially with the lead mining of the nineteenth century, and to consider briefly to what extent the industry has been carried on in recent times.

The actual area in which lead has been mined in Yorkshire may be taken as about one-sixth of the entire county, and is situated in the North and West Ridings, in the mountainous regions towards the head waters of rivers—the Tees (where it divides Yorks from Durham and Westmorland), the Yorks Lune, the Swale and its great tributary Arkle Beck, the Ure, the Nidd, the Wharfe, the Aire, and the Ribble. Taking these districts *seriatim*, commencing in the north, we find that the Tees area contained some thirteen or fourteen distinct mines; none worked since about 1870. Lunedale had about half a dozen, one of which, that known as Lunehead, was extensive, and has been reopened recently. For the next two areas—those of Arkengarthdale and Swaledale—it is impossible at the moment to register any definite number, but they may be said to have run into hundreds at one time or another.

Two especially, Hurst Mine, in Arkengarthdale, and that at Old Gang, in Swaledale, were notorious for centuries, and the output from them was enormous.

From the latter mine it is said that at one time, about the middle of the nineteenth century, some 3,000 tons per annum were produced. At Hurst the Romans are said to have had a penal settlement, and lead was probably mined there, not only by them, but who shall say how long before? Now Hurst is grim and desolate like the 'Deserted Village,' though the hills still cover thousands of tons of rich ore, which twentieth-century enterprise may yet acquire. Old Gang, in Swaledale, is still kept going, but is gradually becoming worked out; though there can be little doubt that many other veins in its proximity may be worked to profit at to-day's selling price if facilities for carriage were provided.

In Wensleydale, over the ridge southward we find at least forty distinct mines, and some of these were very remunerative, notably that of Keld Heads, near Wensley. Flooding of the mine at a time when the market price was very low was the cause of closure.

This mine, along with several others, was closed down during the last decade of the century. Continuing southward, in Nidderdale about thirty separate mines have been wrought, those on Greenhow Hill being once among the oldest and most productive in the North of England; Cockhill Level (Greenhow) branched into many miles of levels, from which a great weight of lead was taken; yet the supply is by no means exhausted, for the Bradford Corporation, when recently making their pipe track across Greenhow Moor, cut a very large vein of ore. Mr. Joseph Cradock, J.P., of Stockton-on-Tees, still works at Lolly Scar and Blayshaw Gill Mines in this area.

Wharfedale contributed enormously in the middle of last century from some twelve or fifteen mines, of which Grassington Moor mine was by far the most important. They were closed some thirty years ago.

Of Airedale but little need be written, for, with the exception of the great Cononley Mine, there were only a few lesser trials.

In the last area, that of Ribblesdale, three mines were worked, namely, at Rimmington, Skelhorn, and two in the Bolland district near Slaidburn.

Skelhorn Mine was worked centuries ago, and was rich in silver, like many of the Yorkshire mines.

So far as can be ascertained there are possibilities for future enterprise in nearly all the areas mentioned, but prospectors will do well to observe the causes which led to the close of the various workings before. Briefly they are as follows:—

(a) The continued low price of lead, largely influenced by Spanish importation.

(b) The spirit of mine speculation in the worst sense of the term, whereby the mines were bought up and floated for the sake of immediate gains from their flotation.

(c) The system of remuneration of the miners themselves having been changed from the 'bing system' to the 'fathom system.'

(d) The fact that landlords in many districts purposely put difficulties in the way of miners on account of the value of their lands for grouse-rearing, and because of the pollution of their rivers owing to the lead-washing.

TUESDAY, AUGUST 7.

The following Papers were read:—

1. *The Unemployed.* By C. J. HAMILTON, B.A.

The author attempted an analysis of the industrial and social character of the unemployed, based upon the returns to certain distress committees under the Unemployed Workmen's Act. Taking typical districts it is possible to obtain fairly exact statistics of age, wage, and trade distribution. These prove the following facts:—

(a) That 86 per cent. of the applicants are 'unskilled.'

(b) That 56 " " " are 'casual' labourers.

(c) That 37 " " " owe their position to one or more of the following causes—age, inefficiency, or bad character.

(d) That 22 " " " are of good character, possessing good industrial records.

(e) That 41 " " " are of indifferent efficiency, and have only an indifferent record.

(f) That 16 " " " are or have been members of a recognised trade-union.

(g) That 14 " " " are or have been members of a friendly society or slate club.

The paper then briefly compared the following chief causes of suffering from unemployment in order to indicate the relative importance of remedial measures:—

(1) Long-period fluctuations in the volume of industry.

(2) Imperfect organisation of the labour market in respect of certain trades—*e.g.*, the docks, building, &c.

(3) Imperfect organisation of thrift.

(4) Insufficient provision for the training of skilled labour.

2. *Labour Exchanges and the Unemployed Problem.*

By W. H. BEVERIDGE, M.A., B.C.L.

The function of a Labour Exchange is to reduce friction in the process of adjusting local demand and supply in the labour market. Apart from unemployables, the mass of distressed unemployed are of three types: (1) Men permanently displaced from their chosen occupations; (2) men exceptionally and temporarily thrown out by seasonal or cyclical depression of trade; (3) irregular or casual workmen—the chronically under-employed. The third type is (a) in bulk the most serious part of the unemployed problem—in London three out of four of the distressed unemployed belong to the chronically under-employed class; (b) a direct product of industrial friction.

The industrial characteristics and functions of the under-employed class, as illustrated by the dock or wharf labourer. The casual dock labourer is neither unemployable nor superfluous; he is required to be always or recurrently available to meet fluctuations of work, though not constantly employed. The numbers required at any one dock department or wharf depend upon the flow of work at that one place. But the number of individuals required for the work of a district, including many docks or wharves, depends not only upon the total flow of work in that district, but also upon the mobility of labour within it. The London and India Docks in 1887 and in 1904. In any occupation where work is irregular the unification of the disconnected fluctuating labour demands of many businesses into a single steadier demand centralised at a labour exchange enables a large stagnant reserve of labour accumulated round the separate places of employment to be replaced by a smaller mobile reserve directed from the exchange, in which each individual performs correspondingly more work and earns more regular wages.

Application of the foregoing argument to (a) other irregular employments—*e.g.*, builders' and contractors' work; (b) the whole of industry. Increase of mobility means an increase in the working efficiency of labour: less looking for work, more work and wages.

Desirability and practicability of furthering the mobility of labour by means of a connected system of labour exchanges. Consideration of current objections to: (1) its desirability—*e.g.*, that labour is already sufficiently mobile, that employers have as many men as they want, that the change would simply give more regular work to one set of men at the cost of another set, who would be thrown out of work altogether; (2) its practicability—*e.g.*, that labour exchanges have been tried and failed, that employers will not agree to take their men from a labour exchange. All these objections can be met separately. They are subject also to the general answer that the casual labour question has to be solved somehow, and to the negative argument that it cannot be solved by any other means than the extinction of casual employment. Temporary assistance of the under-employed man is useless, and his permanent removal to another occupation leaves the cause of his under-employment still acting. Labour exchanges have never been taken seriously in this country because people have been content to describe their function as the increasing of the fluidity of labour (an end of no obvious practical advantage to anybody) without going on to observe that greater fluidity means greater working efficiency, less leakage of labour power in passing from one employment to another, more regular earnings. The question of marketing is as important in regard to labour as in regard to ordinary commodities.

Conclusion: Labour exchanges touch all branches of the unemployed problem.

(1) They will not save men from being displaced by the introduction of machinery, but they will help these men to find fresh openings. (2) They will not prevent industrial depressions, but (a) they will make more general the use of subsidiary trades, and (b) by raising, as is described in the next sentence, the whole standard of life and earnings at the bottom of the industrial scale they will make thrifty provision against exceptional distress more possible. (3) Labour exchanges in modifying casual employment lead the way to the

abolition of a system of employment and an under-employed class which are exactly analogous to sweating and the sweated class. Whether the efforts being made in London and elsewhere to establish labour exchanges succeed now or fail, sooner or later, after little or much bitter experience of other methods, the adoption of their underlying principle will be forced upon society.

3. *Some recent Investigations in Home Work.*

By Mrs. J. RAMSAY MACDONALD.

Industries carried on in the homes of the workers are the most subject to the evil effects of competition. Recent investigations by the Women's Industrial Council, Scottish Council for Women's Trades, 'Daily News' Committee, &c. Variety of trades and of districts. What they show as regards:—

1. Wages—average of piece rates—irregularity of employment—deductions for materials, &c. How out-relief acts to keep down standard of wages.

2. Hours.

3. Child labour.

4. Sanitary conditions.

Neglect of inspection of outworkers by local authorities, as shown by Home Office return of June 25, 1906.

Suggestions towards improved conditions. Licensing as proof of inspection for sanitation and overcrowding. Education *versus* child labour and unskilled labour. Enforcement of Particulars clause, Truck Acts, and Fair Wages clause in public contracts. Only palliative measures possible as long as the competitive system of industry for private profit holds sway.

WEDNESDAY, AUGUST 8.

The following Papers were read:—

1. *Economic Theory and Proposals for a Legal Minimum Wage.*

By H. B. LEES SMITH, M.A.

Two lines of policy suggested: I. A minimum wage determined separately for each of certain selected trades. II. A general minimum determined, by physiological considerations, for all trades without distinction.

I. Analysis of results of first proposal.

Neglecting, for the moment, considerations arising from possible changes in the efficiency of the wage-earners, the increased wage may come from three sources: (1) A fall in the wages of the more highly paid labourers. Improbability. (2) An increase in the price of the commodity. Result: A certain amount of labour and capital hitherto employed in production of commodity forced to seek other employment even less remunerative. Inquiry into how much labour and capital will be displaced. Analogy between effects of a minimum wage and of the action of a trade-union which adopts device of restriction of numbers. (3) A fall in profits. Ultimate results same as those following from an increase in price of commodity.

II. A general minimum imposed on all trades together. In this case labour displaced from one trade has not resource of accepting lower wage in another. Possibility of creating a class prevented by State from obtaining employment. Hence discussion of a minimum wage leads to problem of an entirely different character.

Considerations arising from possible changes in efficiency of labour and capital:—

1. Argument that if the employers paid more, the labour would quickly be worth more. Modifications due to fact that increase of wages accompanied by greater irregularity of employment.

- 2. Effect of fear of unemployment in stimulating wage-earners.
- 3. Invention of improved processes and substitution of capital for labour.

Examination of doctrine of 'parasitic trades.'

Effect of a legal minimum wage upon international trade.

Inquiry how far above theoretical reasoning supported by experience of Australia and New Zealand.

2. *Labourers and the Land: Yorkshire.* By ROBERT E. TURNBULL.

The population of Yorkshire in 1901 was found to be 3,590,750: of these 3,025,000, or $84\frac{3}{10}$ per cent., resided in urban districts and 565,000, or $15\frac{7}{10}$ per cent., in rural districts.

In urban districts men and boys of all ages formed only 48.42 per cent. of the urban population.

In rural districts the proportion was 50.58 per cent.

In urban districts the number of women and girls of all ages exceeded the number of men and boys by about 95,500 = $6\frac{1}{2}$ per cent.

In rural districts men and boys of all ages exceeded the number of women and girls by over 6,500, or by $2\frac{1}{2}$ per cent.

The area of Yorkshire is 3,887,700 acres; in 1901 the total area under crops and grass, exclusive of mountain and heath land, was 2,735,100 acres, or over 70 per cent. of the area of the county.

Every year Yorkshire is becoming less rural and more urban in character. It may be well to note some of the principal changes revealed by the census and agricultural returns for 1901. There was an increase in 1901 as compared with 1891 of nearly 377,000 in the population, or $11\frac{7}{10}$ per cent. In urban districts the increase was over 340,000, or $12\frac{2}{3}$ per cent.

In rural districts the increase was under 36,500, or $6\frac{2}{10}$ per cent.

In 1891 the urban districts occupied about 571,400 acres; in 1901 about 606,600 acres, an increase of 35,200 acres, or $6\frac{2}{5}$ per cent. Rural districts decreased in area by nearly $1\frac{1}{17}$ per cent.

In 1891 the area of land in the urban districts equalled $1\frac{1}{8}$ acre per family of five persons; in 1901 almost exactly one acre. In the rural districts in 1901 the area equalled 29 acres per family of five persons, or $2\frac{1}{3}$ acres less per family than in 1891.

In 1901 the total area of arable land and permanent pastures and meadows was 4 per cent. more than in 1871. In grasslands the increase was $27\frac{1}{2}$ per cent., but in arable land there was a decrease of $16\frac{2}{3}$ per cent., or 230,800 acres. This great decrease in the area of arable land, which necessarily requires far more labour per acre than grassland, took place chiefly between 1881 and 1891. But while the area under the plough decreased, the quantity of livestock increased considerably. Estimating the average live weight of horses of all ages (included in the agricultural returns) at 8 cwt., cattle of all ages at 6 cwt., sheep and lambs at $\frac{3}{4}$ cwt., and pigs at 1 cwt., the weight of all stock was as follows:—

						per acre.
In 1871	.	.	.	.	5,093,500 cwt.	= 1.94 cwt.
In 1901	.	.	.	.	6,008,500 cwt.	= 2.19 cwt.

Increase in total weight in 1901, 915,000 cwt., or nearly 18 per cent.

In 1901 as compared with 1871 the number of horses was larger by 24 per cent.; cattle $24\frac{7}{10}$ per cent.; sheep and lambs by $4\frac{2}{3}$ per cent.; in the case of pigs there was a decrease of $6\frac{7}{10}$ per cent.

Calculating the value of manual labour applied to arable land at 35s. per acre, and in connection with grassland at 10s. per acre, it will be seen that the outlay on arable land on manual labour was nearly 404,000l., or $16\frac{2}{3}$ per cent., less in 1901 than in 1871.

On the other hand, the outlay on grassland was more by about 169,000l., or by over $27\frac{1}{2}$ per cent.

The net decrease on this basis was 235,000*l.*, or $7\frac{2}{3}$ per cent.

This reduction of 235,000*l.* represents the value of the labour of 5,220 men, earning 45*l.* each in the year. The reduction in the number of men employed has no doubt been much greater than these figures indicate, because less attention has lately been given to hedging and ditching, and to farm roads and repairs generally. Improved machinery has undoubtedly helped to reduce the labour bill, more especially in connection with hay time and harvest.

In 1901 there were 1,358,000 men and boys in Yorkshire ten years old and upwards: of these 1,166,000, or $85\frac{1}{10}$ per cent., were engaged in the various occupations; of these only about 82,000, or about 7 per cent., returned themselves as farmers or as being employed by farmers. The number of men and boys employed by farmers was 57,600: of these 10,600, or over 18 per cent., were sons or other relatives of farmers.

The following table appears to point forcibly to one of the great advantages of living in a rural rather than in an urban district. It will be seen that the proportion of persons who attain a good old age is considerably greater in rural than in urban districts.

Men and Women	In Urban Districts	In Rural Districts	Total Urban and Rural	Urban	Rural
	No.	No.	No.	Per cent.	Per cent.
Age 65 and upwards .	113,400	33,160	146,560	3·74	5·86
Age 55 " .	288,760	70,400	359,160	9·54	12·45
Age 50 " .	412,950	94,270	507,220	13·65	16·67
Age 45 " .	564,470	121,960	686,430	18·65	21·57

In the various branches of house building and works of construction, 110,960 men and boys, employers and employed, were engaged: of these only 4,127, or $3\frac{7}{10}$ per cent., were, in 1901, 65 years old and upwards, whereas of the 81,834 men and boys, employers and employed, engaged in farming, 6,484, or $7\frac{9}{10}$ per cent., were 65 years old and upwards. Of the 24,244 farmers (men) 4,057, or $16\frac{7}{10}$ per cent., were 65 years old and upwards. Of 1904 clergymen of the Established Church, 238, or $12\frac{1}{2}$ per cent, were 65 and upwards. These resided some in urban and some in rural districts. The actual number of persons employed by farmers was not recorded in any census before 1901, but the number of persons employed by farmers in England and Wales, exclusive of all women and children who were related to their employers, and also exclusive of boys under 15 who were related to their employers, was, in 1881, 965,200; in 1891, 866,000; in 1901, 727,100. The decrease in 1901 as compared with 1881 was 238,100, or $24\frac{2}{3}$ per cent. The decrease in 1901 as compared with 1891 was 138,900, or 16 per cent. During the same period there was a large increase in the number of persons employed on the land as gardeners, woodmen, and nurserymen. Country labourers are now better fed, better clothed, and in some respects better educated than in any former period.

In many districts the homes of agricultural labourers are less satisfactory than could be desired.

In order to encourage the best class of cattlemen, shepherds, and field labourers to remain as farm workmen an adequate supply of comfortable cottages should be provided, each having sufficient good land attached to provide an ample supply of vegetables, fruit, and milk for the labourer and his family. A home of this kind has always been found to be an invaluable school for children, and not infrequently it has proved to be a stepping-stone to a larger holding.

3. *Monthly Index Numbers of Prices for 1906.*

By CLARENCE S. HOWELLS and H. STANLEY JEVONS, M.A., B.Sc.

The wholesale prices of forty-three commodities, as quoted by the 'Economist,' have been averaged for each month and their unweighted geometric mean taken,

referring to January as base, with the following results: January (base), 100; February, 100·74; March, 100·80; April, 101·12; May, 103·04; June, 103·87; July, 103·12.

4. *Industrial Betterment.* By MARY E. WOOD.

Definition:—

Increasing tendency to only engage the *young* in factories and workshops.
A factory thus becomes the chief factor in the development of the worker.

Employers are responsible for the—

- A. Physical Development of the employee.
- B. Intellectual " " "
- C. Moral " " "

Industrial Betterment aims at securing:—

A. *Physical Development*, by good ventilation, sunshine, light, recreation grounds where possible. Doctor and dentist on the factory staff. Dining-rooms, well-cooked cheap food, &c.

B. *Intellectual Development*, by 'domestic school' classes in cookery, cutting-out and making clothes, laws of health, &c., for all girl employees from fourteen to seventeen, during work hours. Factory library. Factory magazine. Suggestion prizes. Education of the eye by pictures and flowers in workrooms. Allotments.

C. *Moral Development.* Men and women working in separate rooms.

Careful choice of overlookers.

Good lighting in the factory.

All girls leave when they marry.

Some Results:—

General health good, consequently good 'timekeeping,' better work, good wages ('piece-work') earned.

Greater command of labour.

Better type of labour attracted.

The percentage of those who leave steadily decreases, and consequently the average length of time spent at the works by each employee increases.

SECTION G.—ENGINEERING.

PRESIDENT OF THE SECTION—J. A. EWING, M.A., LL.D., F.R.S.

THURSDAY, AUGUST 2.

The President delivered the following Address:—

I INTEND to devote this Address to considering in certain aspects the inner structure of metals and the manner in which they yield under strain. It will not be disputed that this is a primary concern of the engineer, who in all his problems of design is confronted by the limitations imposed on him by the strength and elasticity of the materials he employs. It is a leading aim with him to secure lightness and cheapness by giving to the parts such dimensions as are no larger than will secure safety, and hence it is of the first importance to know in each particular case how high a stress may be applied without risk of rupture or of permanent alteration in form. Again, the engineer recognises the merit, for structural purposes, of plasticity as well as strength, and in many of his operations he makes direct use of that property, as in the drawing of wires and tubes or the flanging of plates. He is concerned, too, with the hardening effect that occurs in such processes when work is expended on permanently deforming a metal in the cold state, and also with the restoration to the normal condition of comparative softness which can be brought about by annealing. Nor can he afford to be indifferent to the phenomena of 'fatigue' in metals, which manifest themselves when a piece is subjected to repeated alternation or variations of stress—fatigue of strength and fatigue of elasticity, which, like physiological fatigue, admits under some conditions of rest-cure, inasmuch as it tends to disappear with the lapse of time. No apology need be made in selecting for a Presidential Address to Section G a subject that touches so many points of direct practical interest to engineers. It is a subject which has for me the additional attraction of lying in the borderland between engineering and physics—a borderland in which I have often strayed, and still love to stray, and I enter it to-day even at the risk of wandering into regions which, to engineers, may seem a little remote from home, regions where the landscape has, perhaps, a suspicious likeness to that of the country over which the learned men of Section A hold rule.

To engineers, quite as much as to physicists and chemists, we owe in recent years an immense extension of knowledge regarding the structure of metals. This has come about mainly by the intelligent use of the microscope. Take any piece of metal, in the state in which an engineer makes use of it, polish and lightly etch its surface, and examine it under the microscope, and you find that it is a congeries of a multitude of grains, every one of which may be proved to be a crystal. It is true that the boundaries of each grain have none of the characteristics of geometrical regularity which one is apt to look for in a crystal, but the grain is a true crystal for all that. Its boundaries have been determined by the accident of its growth in relation to the simultaneous growth of neighbouring grains—the grains have grown, crystal fashion, until they have met, and the surface of meeting, whatever

shape it may happen to take, constitutes the boundary. But within each grain there is the true crystalline characteristic—a regular tactical formation of the little elements of which the crystal is built up. It is as if little fairy children had built the metal by piling brickbats in a nursery. Each child starts wherever it happens to be, placing its first brickbat at random, and then piling the others side by side with the first in geometrical regularity of orientation until the pile, or the branches it shoots out, meets the advancing pile of a neighbour; and so the structure goes on, until the whole space is entirely filled by a solid mass containing as many grains as there have been nuclei from which the growth began.

We now know that this process of crystal growth occurs not only in the solidification of a metal from the liquid state, but in many cases during cooling through a 'critical' temperature when the metal is already solid. We know also that the process may in certain conditions go on slowly at very moderate temperatures. We know also that the process of annealing is essentially the raising of the metal to a temperature at which recrystallisation may take place, though the metal remains solid while this internal rearrangement of its particles goes on. Whether crystallisation occurs in solidifying from the liquid or during the cooling of an already solid piece it results in the formation of an aggregate of grains, each one of which is a true crystal. Their size may be large or small—in general, quick cooling means that crystallisation starts from many nuclei, and the resulting grains are consequently small; with very slow cooling you get a gross structure made up of grains of a much larger size.

For simplicity of statement I shall ask you in what follows to confine your attention to simple metals, omitting any reference to alloys. Alloys present many complexities, into which we need not at present enter. With simple metals every crystalline grain is made of the same substance: the elementary brickbats are all exactly alike, though there may be the widest variation from grain to grain as regards the form of the grain, and also as regards the direction in which the elementary brickbats are piled. In any one grain they are piled with perfect regularity, all facing one way, like a regiment of perfectly similar soldiers formed up in rows, where each man is equidistant from his neighbours, before and behind, as well as to right and to left. Or perhaps I might compare them to the well-drilled flowers of an early Victorian wall-paper.

It was shown by Mr. Rosenhain and myself¹ that when a piece of metal is strained beyond its limit of elasticity, so that permanent set is produced, the yielding takes place by means of slips between one and another portion of each crystal grain. A part of each crystal slides over another part of the same crystal, as you might slide the cards in a pack. It is as if all the soldiers to one side of a given line were to take a step forward, those on the other side remaining as they were, or as if all the men in the front rows took a step to the left, while those in the rows behind kept their places. In other words, the plasticity which a metal possesses is due to the possibility of shear on certain planes in the crystal that are called 'cleavage' or 'gliding' planes. Plastic yielding is due to the occurrence of this shear; it may take place in three or more directions in a single grain, corresponding to the various possible planes of cleavage, and in each direction it may happen on few or many parallel planes, according to the extent of the strain to which the piece is subjected. Examine under the microscope the polished surface of a piece of metal which has been somewhat severely strained after polishing, and you find that the occurrence of this shear or slip is manifested on the polished surface by the appearance of little steps, which show themselves as lines or narrow bands when looked at from above. To these we gave the name of slip-bands. Just as the piece of metal is an aggregate of crystal grains, the change of shape which is imposed upon it in straining is an aggregate effect of the multitude of little slips which occur in the grains of which it is made up. Each grain, of course, alters its form in the process.

Speaking broadly, this distortion of the form of any one grain by means of

¹ Ewing and Rosenhain, 'The Crystalline Structure of Metals,' Bakerian Lecture *Phil. Trans. Roy. Soc.*, vol. cxciii. A, 1899.

slips leaves it still a crystal. If part of the group of brickbats moves forward, keeping parallel to themselves and to the others, the formation remains regular, except that a step is formed on the outermost rows; the orientation of the elements continues the same throughout. Considerations which I shall mention presently lead to some qualification of this statement. I now see reason to believe that in the process of slip there is a disturbance of the elementary portions or brickbats adjoining the plane of slip, which may alter their setting, and thereby introduce to a small extent some local departure from the perfectly homogeneous orientation which is the characteristic of the true crystal. In very severe straining there may even be a wide departure from true crystalline character. We shall recur to this later; but meanwhile it will suffice to say that substantially the slip which is involved in a plastic strain of moderate amount is a bodily translation, parallel to themselves, of part of the group of elementary brickbats or molecules which build up the grain. If a crystal whose form has been altered, even largely, by such straining is cut and polished and etched it appears, under the microscope, to be to all intents and purposes as regular in the tactical grouping of its elements as any other crystal.

Further, in the process of straining we have, first, an elastic stage, extending through very small movements, in which there is no dissipation of energy and no permanent set. When this is exceeded, the slip occurs suddenly; the work done in straining is dissipated; if the straining force is removed a strain persists, forming a permanent 'set'; if it continues to act it goes on (within certain limits) producing augmented strain. In general a large amount of strain may take place without the cohesion between the gliding surfaces being destroyed. Immediately after the strain has occurred there is marked fatigue, showing itself in a loss of perfect elasticity; but this will disappear with the lapse of time, and the piece will then be harder than at first. If, on the other hand, a process of alternate straining back and forth be many times repeated, the piece breaks.

These are now familiar facts. Can we attempt to explain them on the basis of a molecular theory which will at the same time offer a clue to the process of crystal-building as we find it in metals? I venture to make this Address the occasion of inviting attention to some more or less speculative considerations which may be held to go some little way towards furnishing the material for such an explanation.

At the Leeds Meeting of this Association, in 1890, it was my privilege to bring forward certain contributions to the molecular theory of magnetism, and to show a model which demonstrated that the rather complex phenomena of magnetisation were explainable on the very simple assumption that the magnetic molecules are constrained by no other forces than those which they mutually exert on one another in consequence of their polarities.¹ From this were found to result all the chief phenomena of permeability and magnetic hysteresis. Let us attempt to-day to apply considerations of a similar character to another group of physical facts, namely, those that are associated with the crystalline structure of metals and with the manner of their yielding under strain. Just as in dealing with magnetic phenomena, I take as starting-point the idea that the stability of the structure is due to mutual forces exerted on one another by its elementary parts or molecules, and that the clue to the phenomena is to be sought in the play of these mutual forces when displacement of the molecules occurs.

Iron and most of the useful metals crystallise in the cubic system; for simplicity we may limit what has to be said to them. Imagine a molecule possessing polarity equally in three directions, defined by rectangular axes. We need not for the present purpose inquire to what the polarity along the axes is due; it will suffice to assume that the molecule has six poles, three positive and three negative, and that these repel the like and attract the unlike poles of other molecules. We may make a model by using three magnetised rods fixed at right angles to one another at their middle points. I imagine, further, that the

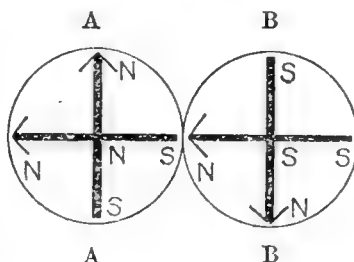
¹ 'Contributions to the Molecular Theory of Induced Magnetism,' *Proc. Roy. Soc.* vol. xlviii. June 19, 1890, or *Phil. Mag.*, September, 1890.

molecule has an envelope in the shape of a sphere, which touches the spherical envelopes of its neighbours, and assume that these spheres may turn on one another without friction.¹

Think now of the process of crystal-building with a supply of such spherical molecules for brickbats. Starting with one molecule, let a second be brought up to it and allowed to take up its place under the action of the polar forces. It will have a position of stability when a positive pole in molecule A touches (or lies in juxtaposition to) a negative pole in molecule B, with the corresponding axes in line, and when the further condition is satisfied that the axes in molecule B whose poles are not touched by A are stably situated with respect to the field of force exerted by the poles of A.

In other words, we have this formation:—

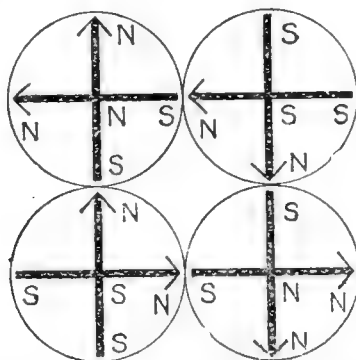
FIG. 1.



For convenience of representation in the diagram the poles are distinguished by the letters N. and S., but it must not be assumed that the polarities with which we are here concerned have anything to do with magnetism.

Suppose, now, that the crystal is built up by the arrival of other molecules, each of which in its turn assumes the position of maximum stability consistent with formation in cubic or normal piling. The group in that case takes an arrangement which is essentially a repetition of this quartette:—

FIG. 2.



Along each row the polarity preserves the same direction, but the polarity of each row is opposite to that of each contiguous parallel row. This description applies equally to all three axes. The whole group (fig. 3) consists of the quartettes of fig. 2 piled alongside of and also on top of one another. In this way we arrive at what I take to be the simplest possible type of cubic crystal.

In this grouping each molecule has the alignment giving maximum stability, and it seems fair to assume that it will take that alignment when the crystal grain is formed under conditions of complete freedom, as in solidifying from the

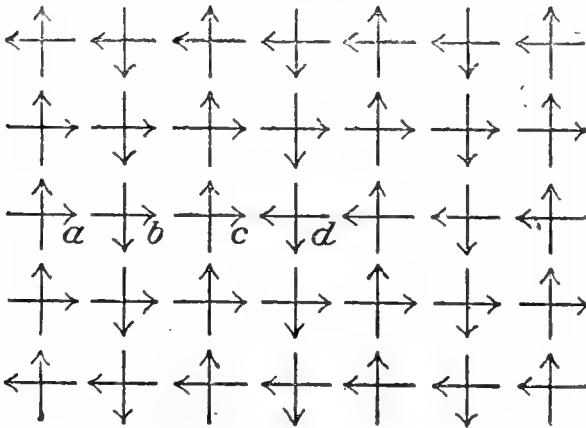
¹ Or, let the envelope be a shell of any form, inside of which the axes of polarity are free to turn as a rigid system,

liquid state. As a rule, the actual process of crystal-building goes on dendritically; branches shoot out, and from them other branches proceed at right angles, leaving interstices to be filled in later. We have, therefore, to conceive of the molecules as piling themselves preferably in rows rather than in blocks, though ultimately the block form is arrived at. In this position of maximum stability each molecule has its six poles touching poles of contrary name.

Now comes a point of particular importance. Imagine two neighbouring molecules in the same block to be turned round, each through one right angle, in opposite senses. They will now each have five poles touching five poles of contrary name, but the sixth pole will touch a pole of the same name as itself. They are still stably situated, but much less stably than in the original configuration, and they will revert to that configuration if set swinging through an angle sufficient to exceed the limited range within which they are stable in the new position.

Similarly we may imagine a group of three, four, or more molecules, each to be turned through a right angle, thereby constituting a small group with more or less stability, but always with less than would be found if the normal configuration had been preserved. The little group in question may be made up of molecules in a row, or it may be a quartette or block, or take such a form as a T or L.

FIG. 3.



A sufficient disturbance tends to resolve it into agreement with the normal tactics of the molecules which build up the rest of the grain.

It is conjecturally possible that small groups of this kind, possessing little stability, may be formed during the process of crystallisation, so that here and there in the grain we may have a tiny patch of dissenters keeping one another in countenance, but out of complete harmony with their environment.

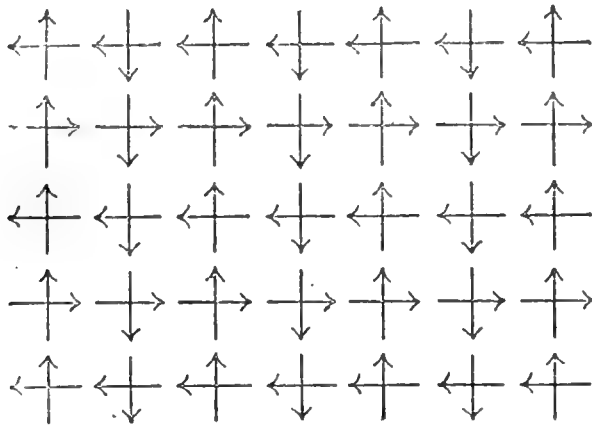
If this happens at all during crystallisation, it would seem less likely to happen in free crystallisation from a liquid state than in the more constrained process that occurs when a metal already in the solid state recrystallises at a temperature far below its melting-point. Though rare or absent in the first case, it might occur frequently in the second. There are differences in the appearance of crystal grains under the microscope in metal as cast and in metal as recrystallised in the solid state, of which this may be the explanation. It may also explain a difference pointed out by Rosenhain,¹ that the slip lines in cast metal are straight and regular, whereas in wrought iron and other metals which have recrystallised in the solid they rarely take a straight course across the crystal, but proceed in jagged, irregular steps. These may be due to the presence here and there of small planes of weakness, resulting from the existence of what I have called dissenting groups. Again, these groups, possessing, as they do, less stability than

¹ Rosenhain, 'The Plastic Yielding of Iron and Steel,' *Journal of the Iron and Steel Institute*, No. 1 for 1904, p. 335.

their normal neighbours, may be conjectured to differ from the normal parts of the grain in respect of electrolytic quality, and to be more readily attached by an etching reagent. Hence, perhaps, the conspicuous isolated geometrical pits that appear on etching a polished surface of wrought iron.

It will help in making clear these points, and others that are to follow, if we study the action of a model formed by grouping a number of polarised 'molecules' in one plane, supporting them on fixed centres, about which they are free to turn. In the model before you the centres are uniformly spaced in rectangular rows, and the 'molecules' are + shaped pieces of hardened steel, strongly magnetised along each of the crossed axes, each having, therefore, two north poles and two south poles. The third axis is omitted in the model, the movement to be studied with the help of the model being movement in one plane. On placing these 'molecules' on their centres they readily take up the position already indicated in fig. 3. Each one within the group has its four poles in close proximity to four poles of contrary name, and is, therefore, highly stable. If disturbed by being turned through a small angle, and let go, it swings back, transmitting a wave of vibration through the group, which is reflected from the edges, and is finally damped out in the model by pivot friction and air friction. We may

FIG. 4.



assume some damping action (say by the induction of eddy-currents) in the actual solid, of which the model may be taken as a very crude representation.

By turning two molecules carefully round together, each through one right angle in opposite senses, we set up a dissenting pair, whose equilibrium has feeble stability. A slight displacement, such as might be produced by the transmission of a vibrational wave, breaks them up, and they swing back to the normal configuration, giving out energy, which is taken up by the rest and is ultimately dissipated. By making the dissenting coterie consist of three or more we can give it additional strength.

An example is shown in fig. 4, where the three molecules marked *a*, *b*, and *c* are turned round in this way.

Notice that the normal molecule *d*, adjoining a line of such dissenters, is in a peculiar position. His neighbours present to him three N. poles and one S. pole. He has the choice of conforming to the majority, or of throwing in his lot with the dissenters; and he has a third possible position of equilibrium (very feeble equilibrium) which is reached when his two S. poles are turned until the one neighbouring south pole faces just between them. I have laboured these points a little because they seem important when we come to speak of the effects of strain.

Consider now the straining action, which we may imitate in the model by sliding one part of the group past the other part. For this purpose the centres are cemented to two glass plates which can slide parallel to one of the axes.

At first, when the displacement by sliding is exceedingly small, the strain is a purely elastic one. The molecules adjacent to the plane of sliding pull one another round a little, but without breaking bonds, and if in this stage the strain is removed, by letting the plate slide back to its original position, there is no dissipation of energy. The work done in displacing the molecules is recovered in the return movement. We have here a representation of what happens between each pair of adjoining rows in the elastic straining of a metal. So far the action is within the limit of elasticity; it leaves no permanent effect: it is completely reversible.

But now let the process of straining be carried further. The opposing molecules try to preserve their rows intact, but a stage is reached when their resistance is overcome; the bonds are broken, and they swing back, unable to exert further opposition to the slip. The limit of elasticity has now been passed. Energy is dissipated; set has been produced; the action is now no longer reversible. The model shows well the general disturbance that is set up in molecules adjoining the plane of slip, which we may take to account for the work that is expended in a metal in producing plastic strain.

Moreover, when the slip on any plane stops and the molecules settle down again, the chances are much against their all taking up the normal orientation which they had before the disturbance. What I have called dissenting groups or unstable coteries are formed as a result of the disturbance. Here and there like poles are found in juxtaposition. Viewed as a whole, the molecular constitution of the metal in the region adjacent to the plane of slip is now uncertain and patchy. It includes parts whose stability is much less than normal. Individual molecules or small groups in it are very feebly stable; a touch would make them tumble into positions of greater stability.

Observe how all this agrees with what we know about the nature of plastic strain through experiments on iron or other metals. Its beginning is characteristically jerky. Once the critical force is reached, which is enough to start it, there is a big yield, which will not be stopped even by reducing the amount of the straining force.

Again, we know that there is a slow creeping action that continues after the straining force has done its main work. I ascribe this to the gradual breaking up of the more unstable groups which have been formed during the subsidence of disturbance in the earlier stage of the slip.

Further, we know that overstrained iron is very imperfectly elastic until it has had a long rest, or until it has been raised for a short time to a temperature such as that of boiling water.¹ This is to be expected when we recognise the presence of unstable individuals or groups resulting from the overstrain. When the elasticity of the overstrained piece is tested by removing and reapplying the load, some of these tumble into new positions, making irreversible movements, which dissipate energy and produce hysteresis in the relation of the strain to the stress although the strain is quasi-elastic. At ordinary temperatures these unstable groups are gradually becoming resolved, no doubt through the action of the molecular movements that are associated with heat, and hence the slow progressive recovery of perfect, or nearly perfect, elasticity shown by the experiments of Muir. Let the temperature be raised and they disappear much more quickly; in warm surroundings the rest-cure for elastic fatigue does not need to be nearly so long.

Rosenhain² has recently shown that after the slip-bands on the surface of an overstrained specimen have been obliterated by polishing, traces of them will reappear on etching if only a short interval of time is allowed to lapse since the overstraining; but if time is given for complete recovery no traces are found. This is in remarkable agreement with the view now put forward, that the layers contiguous to the surface of slip contain for a time comparatively unstable

¹ J. Muir, 'On the Recovery of Iron from Overstrain,' *Phil. Trans.*, vol. cxiii. A, 1900.

² *Journ. Iron and Steel Institute*, 1906.

groups. They are consequently different from the normal metal until the unstable groups are resolved, and the temporary difference manifests itself on etching, provided that is done while the difference still exists.

From the engineer's point of view a much more important matter than this fatigue of elasticity is the fatigue of strength that causes fracture when a straining action is very frequently repeated. Experiments which I made with Mr. Humfrey¹ showed that this action begins with nothing more or less than slight slip on surfaces where the strain is locally sufficient to exceed the limit of elasticity. An alternating stress, which makes the surfaces slip backwards and forwards many thousands, or it may be millions of times alternately, produces an effect which is seen on the polished surface as a development of the slip lines into actual cracks, and this soon leads to rupture.

We have, therefore, to look for an effect equivalent to an interruption of continuity across part or the whole of a surface of slip, an effect progressive in its character, becoming important after a few rubbings to and fro if the movement is violent, but only after very many rubbings if the movement is slight.

That there is a progressive action which spreads more or less into the substance of the grain on each side of the original surface of slip was clearly seen in the experiments referred to. It was found that a slip-band visible on the polished surface of the piece broadened out from a sharply defined line into a comparatively wide band with hazy edges, and this was traced to an actual heaping up of material on each side of the step which constituted the original line.

I think this suggests that under alternating stresses which cause repeated backward and forward slips, these do not occur strictly on the same surface in the successive repetitions, and hence the disturbance spreads to some extent laterally. It may be conjectured that slip on any surface leaves a more or less defective alignment of the molecular centres; that is to say, the rows on one side of the plane of slip cease to lie strictly in line with those on the other side. If this occurs over neighbouring surfaces, as a result of slips or a number of parallel planes very close together, the metal throughout the affected region loses its strictly crystalline character, and with it loses the cohesion which is due to strict alignment.

Mr. G. T. Beilby, in a very suggestive paper,² has advanced grounds for believing that portions of a metal may pass from a crystalline to an amorphous formation under the mechanical influence of severe strain, as in the hammering of gold leaf or the drawing of wire, and that this occurs in the polishing of a metallic surface, and also in the internal rubbing which takes place at a surface of slip within the grain. In both cases he suggests the formation of an altered layer. When a polished metal surface is etched, the altered layer is dissolved away, and the normal structure below it is revealed.

Without accepting all Mr. Beilby's conclusions, I think the idea of an altered and more or less amorphous layer is supported by the considerations I am now putting forward. We have assumed that in normal crystallisation the inter-molecular forces lead to a normal piling, in which each molecule touches six neighbours. But it may be conjectured that some of them may take up pyramidal piling (touching twelve others) under the compulsion of strong forces—such forces, for example, as act on the superficial molecules of a surface that is being polished.

If this also occurs at a surface of slip, it gives us a clue to several known facts. It at least assists in explaining the familiar result that metal is hardened by straining in the sense of being made less plastic. Again, it accounts for the general increase of density which is found to take place in such an operation as wire drawing. Further, if a local increase of density occurs in the interior of a grain through piling of some molecules in the closer manner where repeated slips are going on, the concentration of material at one place requires it to be taken from another; in other words, the closer piling tends to produce a gap or crack in

¹ Ewing and Humfrey, 'The Fracture of Metals under Repeated Alternations of Stress,' *Phil. Trans.*, vol. cc. A, 1902.

² Beilby, 'The Hard and Soft States in Metals,' *Phil. Mag.*, August 1904.

the neighbourhood where it occurs. This is consistent with what we know of the development of cracks through repeated alternations of strain.

Recourse to the model shows that with pyramidal piling the polar axes point in so random a manner that the aggregate may fairly be called amorphous. To illustrate this a group is shown with centres fixed at the corners of equilateral triangles.

It is obvious that any pyramidal piling at a surface of slip tends to bar further slip at that particular surface. Hence not only the augmented hardness due to strain, but the tendency in repeated alternations to lateral spreading of the region on which slip occurs. The hardness due to straining is, of course, removed when we raise the metal to such a temperature that complete recrystallisation occurs, normal piling being then restored in the new grains.

Taking a previously unstrained piece, it is clear that the facility with which slip will occur at any particular surface of slip in any particular grain depends not only on the nature of the metal and on the orientation of the surface in question to the direction of the stress, but also on the amount of support the grain receives from its neighbours in resisting slip there. In other words, for a given orientation of surface the resistance to slip may be said to consist of two parts; one is inherent in the surface itself, and the other is derived from the position of the grain with reference to other grains.

To make this point clear, think of a grain (under stress) in which there is a gliding surface oriented in the most favourable direction for slipping. Slip on this surface can take place only when its yielding compels the neighbours (which are also under stress) to yield with it, and the surfaces in these on which slip is compelled to occur are, on the whole, less favourably situated. Hence the original grain cannot yield until the stress is considerably in excess of that which would suffice to make it yield if it stood alone, or had neighbours equally favourably inclined.

Apply this consideration to the case of steel, where there are two classes of grains: the ferrite, which is simply iron, and the pearlite, which is a harder structure. Slip on any ferrite grain is resisted partly by the strength of the surface itself, and partly by the impossibility of its yielding without forcing slip to take place on neighbouring (harder) grains. Now suppose the structure is a very gross one, such as Mr. Stead has shown may be found in steel that is seriously overheated. On the large grains of ferrite in overheated steel the resistance to slip will be but little greater than it would be in iron, and, consequently, under an alternating stress fatigue of strength, leading to rupture, may be produced by a very moderate amount of load. Mr. Stead¹ has shown how the effects of overheating can be removed by the simple expedient of raising the steel to a temperature sufficient to cause recrystallisation—a homœopathic remedy that transforms the gross structure of the overheated metal into an ordinarily fine structure, where no ferrite grain can yield without compelling the yielding of many pearlite grains. Hence we find, as Rogers² has demonstrated by experiment, that steel cured by reheating from the grossness of structure previously produced by overheating, has an immensely increased power to resist the deteriorating effects of often repeated stress.

I trust you will not feel I have abused the license of the Chair in presenting contributions to molecular theory that are for the most part in the nature of speculative suggestions, thrown out in the hope that they may some time lead to fuller and more definite knowledge. Remote as they may seem to be from the concerns of the workaday engineer, they relate to the matter which it is his business to handle, and to the *rationale* of properties, without which that matter would be useless to serve him. We have attempted to penetrate into its very heart and substance in order the better to comprehend the qualities and functions on which

¹ See especially a paper by J. E. Stead and A. W. Richards on 'The Restoration of Dangerously Crystalline Steel by Heat Treatment,' *Journ. of the Iron and Steel Inst.*, No. 2, 1903.

² F. Rogers, 'Heat Treatment and Fatigue of Steel,' *Journ. of the Iron and Steel Inst.*, No. 1, 1905.

the practical work of engineering relies. The man whose daily business leads him through familiar tracks in a forest does well to stray from time to time into the shady depths that lie on either hand. The eyes of his imagination will be opened. He will at least learn his own limitations, and, if he is fortunate, he may gain some clearing on a hilltop which commands a wider view than he has ever had before.

The following Paper was read:—

*Modern Armour and its Attack.*¹ By Major W. E. EDWARDS, R.A.

FRIDAY, AUGUST 3.

The following Papers were read:—

1. *The Removal of Dust and Smoke from Chimney Gases.*²
By S. H. DAVIES and F. G. FRYER.¹

2. *Standardisation in British Engineering Practice.*
By Sir JOHN WOLFE-BARRY, K.C.B., F.R.S.—See Reports, p. 339.

3. *The Deformation and Fracture of Iron and Steel.*
By WALTER ROSENHAIN.

The object of the author was to illustrate the manner in which microscopic examination is able to throw fresh light on the physical behaviour of metals under the action of stresses above the elastic limit; the researches of Professor Ewing and the author on this subject were referred to, and the general conclusions arrived at in those researches were recapitulated, and the most characteristic features of 'slip-bands' were described. Reference was then made to the divergent views and observations of Osmond, and the author's interpretation of these observations was given, especially in reference to the appearance of slip-bands under oblique light, evidence of the author's view being shown by the aid of multi-colour illumination reproduced by a process of colour-photography. The author then referred to the theory of the hard and soft states in metals advanced by Beilby, and, while largely accepting Beilby's ideas, emphasised the importance of the state of temporary mobility which mechanical disturbance confers upon layers of molecules on or near the surfaces of slip; by the aid of this view the author advanced an explanation of the state of semi-plasticity which follows upon over-strain in iron and steel, and also of the process of the recovery of elasticity which follows upon this condition; microscopic evidence in favour of this view being given. The next section of the paper dealt with the phenomena attending plastic deformation in an alloy of iron, nickel, manganese and carbon, discovered by Carpenter, Hadfield and Longmuir ('alloy K'); the author advanced the view, based upon microscopic evidence, that the change of constitution is confined to the surfaces of slip or to twin lamellae.

The following portions of the paper described the method of studying the microscopic surface configuration of specimens of metal by means of transverse sections obtained after the specimen has been embedded in a mass of electrolytically deposited copper or other metal; the applications of this method to the study of slip-bands were first described, photo-micrographs of slip-bands in

¹ Published in *Engineer*, September 7 and 14, 1906.

² Published in the *Electrical Review*, August 10, 1906.

section, showing the true configuration to be that of geometrically oriented steps, were shown. The application of the method to the study of fractures was next dealt with, and photo-micrographs of transverse sections of typical tensile, shock, and bending fractures of iron and mild steel shown under magnifications ranging from 100 to 1,800 diameters. By means of these sections, the exact path taken by the fracture among the various micro-constituents can be traced in the most minute detail, thus throwing fresh light on the mechanical behaviour of the various constituents. Thus, in the case of mild steel, it was shown that in all forms of fracture which are preceded by severe plastic deformation, the fracture passes through ferrite and pearlite areas almost indifferently, while in the case of fractures produced by shock, in such a way that fracture is not preceded by serious deformation, the path of the fracture lies almost entirely through the ferrite areas. The author suggested the explanation that in the case of considerable plastic deformation, the lower plasticity of the pearlite results in the formation of internal fissures just before the adjoining ferrite breaks, so that the ultimate fracture tends to follow these fissures through the pearlite; microscopic evidence in favour of this view was shown. In conclusion, the author pointed out the possibilities opened up by this method in studying the mechanical behaviour of metals having a complex structure, and also in the study of 'mysterious' fractures occurring in practice or in testing.

4. *Segregation in Steel Ingots, and its Effect in Modifying the Mechanical Properties of Steel.*¹ By J. E. STEAD,

5. *Structural Changes in Nickel Wire at High Temperatures.*²
By H. C. H. CARPENTER.

The research has been carried out in order to ascertain, if possible, the reason for a fundamental change in the mechanical properties of nickel wire used as the heating coil of an electrically heated porcelain tube-furnace.

The wire contained 98·60 per cent. nickel, 1·22 per cent. iron, 0·16 per cent. manganese, and a trace of cobalt. Some dissolved gas or gases were also present. The diameter of the wire was $\frac{1}{16}$ th of an inch. The ultimate tensile stress was 35·2 tons per square inch, with a percentage elongation of 34·4 on 3 $\frac{3}{8}$ inches and a percentage reduction of area of about 70. The resistivity at 0° C. was 9·2 microhms-cm. In building the furnace the wire is wound round an unglazed porcelain tube (1 $\frac{1}{4}$ inch external diameter), which is inclosed in a wider one, the intervening space being filled with crushed quartz. The ends of the furnace consist of porcelain slabs which fit into the wider tube, and are bored so as just to allow the passage of the narrower tube. In actual use the wire carries 20 ampères at 50 volts pressure, and a temperature of 1200°–1300° C. can be obtained in the tube. With care the life of such a furnace is usually three or even more months. But sooner or later it breaks down. The wire is then usually found to be so brittle that it can be snapped between the fingers. Occasionally it is still tough, but has become perfectly fibrous. These changes of mechanical properties are accompanied by structural changes which have been studied with the microscope. They are the result of the *combined* influence of heat and electricity, and are not produced by either of these agencies singly.

It appears that the changes are due mainly to two effects, viz., *recrystallisation* and the *penetration of gases*, which are themselves the result of heat and electricity on the metal. The frequent association of brittleness with gross crystallisation has long been known. But the evolution of dissolved or combined gas or gases from nickel and their mode of penetration through and eventual exit from it by means of cracks between the gross crystals are, it is thought, described here

¹ Published in the *Proceedings of the Cleveland Institution of Engineers*.

² Published in *Engineering*, August 17, 1906.

for the first time. These facts are illustrated by photomicrographs in the complete paper. A tentative explanation based on general physical principles is put forward.

6. *On a Magnetic Indicator of Temperature for Hardening Steel.*¹

By WILLIAM TAYLOR.

The author described experiments with a magnetic induction balance used for ascertaining the critical temperature in the heating of steel for hardening. Also a simple magnetic attachment to a muffle furnace used for giving an audible signal when the steel heated in the muffle has reached its critical temperature.

MONDAY, AUGUST 6.

The following Papers were read:—

1. *The New Engineering Laboratories, Edinburgh University, and their Equipment.* By Professor T. HUDSON BEARE, *M.Inst.C.E., M.Inst.M.E.*

The author described the block of buildings completed in the early part of the present year for the Engineering School of Edinburgh University, and gave details of their equipment.

The building is T-shaped, the head of the T facing west. In the head of the T, on the ground floor, are provided large laboratories for the testing of materials and for hydraulics. The first floor is devoted mainly to a laboratory for experimental work which does not require heavy machinery. On this floor there are also a small lecture-room, the departmental library, and the private rooms for the staff.

The back block of the building is also divided into two floors: the lower forms the lecture theatre and the upper the drawing office. The lecture theatre will seat about 120 students, and on the lecturer's table are all the needful appliances for experimental demonstrations, there being steam, gas, and electrical connections. There are also the necessary appliances for darkening the room in order to allow of the free use of lantern demonstrations. The drawing office is a fine room, about 45 feet square, lit entirely from the north and east, the roof being of the saw-tooth pattern, the floor-space giving room for about sixty independent drawing-tables. Special rooms have also been set aside for blue print-work and photography.

A workshop and heat laboratory has been provided for by roofing in and connecting to the main building a piece of ground lying to the north-east of the main building. The workshop and laboratory contains examples of all the ordinary machine-tools, gas-engines, steam-engines, and other plant for experimental research in connection with thermodynamics.

The building is heated by hot water and by steam: an independent boiler-house has been constructed for this purpose, with two large boilers.

A considerable amount of additional apparatus has been installed in these new buildings. The testing laboratory now contains a 100-ton Buckton machine, with the necessary electric motor, pump, and accumulator; a 60,000-lb. Riehle machine; an Amsler 100-ton machine, specially designed for compression and bending work; and a complete installation for the testing of cements, mortars, &c.

In connection with the hydraulic laboratory a water tower has been constructed at the south-east corner of the building; at the top of this tower is a large cast-iron tank, holding about 10,000 gallons, and giving a head of 65 feet above the floor-level of the laboratory. The floor of the laboratory is on two different levels: on the upper level are placed the various turbines, water-wheels,

¹ Published in the *Electrician*, August 24, 1906.

and other hydraulic machines on which experimental investigations will be carried out. The water discharged from these machines passes into one or other of three rectangular channels formed in the floor, and the quantity is measured by allowing the water to pass over weirs. The water then flows into one or other of two large rectangular tanks, each 11 feet square by 5 feet deep, sunk below the lower floor-level of the laboratory, where it is measured again by floats, with rods moving in front of carefully graduated vertical scales. From these lower measuring tanks the water is lifted by an electrically driven 20 horse-power centrifugal pump back to the storage tank in the water-tower. The hydraulic equipment includes a Venturi meter and other forms of meters and a considerable amount of other apparatus for experimental work.

The paper was illustrated by a considerable number of lantern views.

2. *Glow-Lamps and the Grading of Voltages.*¹

By Sir W. H. PREECE, *K.C.B., F.R.S.*

Twenty-five years have passed without much change in the character of carbon filament glow-lamps, but rivals are now springing up which threaten to lower its predominancy. The British Association System of electrical units has become an international language. Their use is universal. The connection between energy, temperature, light, and the properties of matter are now so well known that the production of light is the subject of well-defined laws. The efficiency is indicated by the watts per candle. In regard to the life of the lamp the higher the efficiency the shorter the life. The relative useful life is then easily tested. The useful life is the time the lamp takes to lose 20 per cent. of its specified candle-power. A new graphite filament has recently been produced in the United States which gives greatly improved results. The resistance increases with temperature. It does not fall as at present. Its efficiency is 2.5 watts per candle, and for street lighting when diffused it gives 1.8 watts per candle.

The Nernst lamp with an efficiency of 1.325 watts per candle, the Osmion lamp with an efficiency of 1.5 watts per candle, the Tantalum lamp with a mean efficiency of 2.1 watts per candle, the Zirconium lamp with an initial efficiency of 1.07 watts per candle, and the Mercury vapour lamp were all referred to. The rare metals have the great advantage that like the new graphite their resistance increases with their temperature, which makes them self-regulating. Their light is whiter. The life of carbon lamps is affected very much by variation of voltage, especially when of poor efficiency like all untreated 220-volt lamps. The use of these lamps is extravagant. The author is using 110-volt lamps in series in preference. A 220-volt lamp wastes its own value in every 500 hours when the mean price is 3½d. per unit. The higher the price the shorter the time of waste. All lamps blacken with age and with such regularity that they can be classified according to their usage by comparison with a scale of standard lamps artificially blackened. Thus the useful life is easily determined.

The standard lamps in candle-power are 8, 16, and 32. It is proposed to add 12 candle-power and 25 candle-power. Lamps should comply with a standard specification (which is under consideration), and they should be tested by authorised distributors or by a public institution. The National Physical Laboratory is fully authorised to do this.

Clause 18 of the Electric Lighting Act of 1882, still in force, has an injurious and deterrent influence on the progress of electric lighting, and it needs repealing.

The most serious evils extant are the departures from standards and the great variations of systems and of voltages. Individual faddism seems to have been exercised to see how far it was possible to depart from rule. Of 472 systems only eleven adopt 110 and eighty-two 220 volts.

The rating of lamps sold in the United Kingdom and their branding is in a very unsatisfactory condition. Reliance cannot be placed on the present system.

¹Published in the *Electrician*, August 10, 1906.

It is different with the United States. A comparison made between the two kinds of lamps tells a very discomfoting tale against our manufacturers. Standardisation, the grading of voltages, testing and the enforcement of the Trades Mark Act are the remedies. The Incorporated Municipal Electrical Association should take the matter up. The limited liability companies are too much disunited to hope for joint action. Something is wrong somewhere. 'Made in England' is becoming a reproach to us.

3. *The Advent of Single-phase Electric Traction.*¹ By C. F. JENKIN.

The author called attention to the rapid advance of electric traction on railways, pointed out its advantages, and described briefly the system on which it should be carried out.

Electric traction will not be adopted simply to reduce the cost of hauling trains. The cost of electric hauling may be more or less than that of steam, according to circumstances. The real advantage of electrification is that it will make the line pay better. It will provide a faster, more frequent, and more comfortable service for the public, and consequently will attract a much larger traffic. It will provide means by which this increased traffic can be carried where this cannot be done by steam. Further, it will enable new methods of handling the traffic to be adopted, such as extending the railway service on to the tram lines, providing an express service to every suburban station instead of stopping trains, and developing the traffic on branch lines on an economical basis. Examples of these methods were described in the paper. The advantages of increased travelling facilities to the inhabitants of towns have been pointed out by Mr. Charles Booth, and the author pleaded for a relaxation of the extravagant precautions now demanded for the public safety, and pointed out that these result in far more lives being lost in the crowded slums than are saved by the avoidance of rare accidents.

The merits of the two alternative systems—alternating-current transmission, continuous-current distribution with low-tension third rail; and alternating-current transmission with high-tension trolley wire—were discussed, and the great advantages of the latter were pointed out, together with the superiority of single-phase over three-phase.

The equipment of a single-phase line was then described, the following points being touched on:—

Overhead construction of three different types.

” ” ” under bridges and tunnels.

Section insulators.

Return circuit and its self-induction.

Sucking transformers.

Electrolysis.

Interference with telegraph and telephone circuits.

The advantages of high tension: its safety and reliability.

Trolley bows for high speed.

Single-phase motors: the compensated repulsion and compensated series types.

Control. Contactors. Single-phase magnets.

Generation of power.

In conclusion the author urged the railway companies to proceed with trial lines in order to convince themselves of the advantages and possibilities of the single-phase system.

¹ Published in the *Electrical Review*, August 17 and 24, 1906.

4. *A General Supply of Gas for Light, Heat, and Power Production.*¹By A. J. MARTIN, *M.Inst.C.E.*

The question of a cheap and abundant supply of energy is one of vital importance to this country. During the present Session a large number of Bills for the supply of electrical energy to London have been before Parliament, and a Select Committee of the House of Commons has recently presented a special report on the subject. Though not seeing their way to give the London County Council the powers which they asked for, the Committee 'consider that the provision of cheap electrical power for London is so important and pressing that they do not view with favour the possibility of the question being indefinitely hung up.'

While attention has been concentrated upon electricity as a medium for the supply of light, heat, and power, the claims of gas have been to some extent overlooked, although its field of usefulness coincides very closely with that of electricity.

The late Sir William Siemens used to insist strenuously that gas should be used for all purposes in place of coal, the burning of which in its raw state he denounced as 'a barbarous practice.' The substitution of gas for coal has been greatly impeded by the circumstance that it was first introduced solely as an illuminant, in which light it is still generally regarded. This conception of gas continues to dominate the methods of manufacture and distribution, to the great detriment of users of heat and power.

The main obstacle to the general use of gas for purposes other than lighting is its cost, which varies from 11*d.* per 1,000 cubic feet (at Widnes) to upwards of 7*s.* 6*d.* The higher prices of gas are due to various causes, the chief of which are the standards of illuminating value to which it has to conform, the large capital involved, the disproportionate cost of manufacture on a small scale, and the high prices paid for coal, consequent on the cost of carriage from the collieries. These causes together swell the cost of the gas consumed in this country every year by many millions of pounds. Illuminating standards are now in many cases being relaxed, but not to such an extent as to give the consumer the full benefit to which he is entitled. The effect of high capital charges and that of working on a small scale are automatically reduced with every increase in consumption, and the greater part of the cost of carrying coal may be saved (in the case of London) by making the gas at the pit's mouth, and piping it under pressure to the Metropolis. It is well known among engineers that a pipe line is the cheapest means for transporting anything which can be made to flow. This has long been recognised in the case of water, which no one would think of conveying by rail, except on an emergency, such as recently occurred at Lincoln. Water is piped to Coolgardie, a distance of 352 miles, and petroleum over 400 miles to New York Harbour. The advantage of generating power at the collieries on a large scale and transmitting it to the areas of supply, has been pointed out by the Royal Commission on Coal Supplies, but in this country proposals of this kind have been directed chiefly to the conveyance of electrical energy from the coal-fields. A proposal to supply the Metropolis in this way was laid before the Select Committee, who dismissed it as not suitable.

Gas has many advantages over electricity for transmission purposes. It can be conveyed at less cost and at a much higher efficiency; it can be stored cheaply and without loss, and used at any desired rate, and it requires no conversions, as in the case of high-tension electricity. Moreover, even where electricity is required, it will generally be cheaper to convert the coal into gas and pipe it for use in gas-engines than to generate current direct from coal.

Down to very recently the conveyance of gas under high pressures to long distances would have been regarded as impracticable, owing to various difficulties arising from condensation and leakage and to other considerations. Of late years, however, both natural gas and coal gas have been piped in America to

¹ Published in the *Gas World*, August 11, 1906.

great distances (extending in the case of natural gas to 200 miles) with marked success, and further projects of the kind are under way.

In this country, in the absence of natural gas, either a fuel gas, such as Mond gas or water gas, or coal gas of reduced illuminating power might be used. The latter could probably be sold in London at something like 1s. per thousand cubic feet, at which price it would displace the greater part of the coal now used for heating and power purposes. The larger cities and towns in Lancashire and Yorkshire, and other districts within easy reach of coal-fields, might also with advantage lay down pipe-lines of their own, but smaller and more remote places could only do so in combination—preferably through a board formed on the model of the Metropolitan Water Board—of representatives of the various Corporations and companies interested.

The inauguration of a general supply of cheap gas would have far-reaching consequences. The smoke nuisance, with its appalling death-roll, would be done away with, and the annoyance and damage to property from smoky fogs brought to an end. A cheap and abundant supply of sulphate of ammonia would come to the aid of our distressed agricultural interests. The most far-reaching effect of cheap gas, however, would probably be in stimulating the establishment of manufacturing plants in rural districts, thus helping to relieve the congestion in our overcrowded towns. No single factor has played so great a part in determining the distribution of industries as the existence of natural sources of power, and with gas at such prices as it could be supplied at from the collieries, gas power would be even cheaper than water power.

Last, but in the long run not least, in importance is the part which the substitution of gas for raw coal would play in postponing the exhaustion of our coal-fields.

TUESDAY, AUGUST 7.

The following Papers were read:—

1. *Experiments illustrating the Balancing of Engines.*¹
By Professor W. E. DALBY, D.Sc., M.Inst.C.E.

2. *Recent Advances in Steam Turbines, Land and Marine.*²
By G. GERALD STONEY, M.Inst.C.E.

The author dealt first with the development in the use of steam turbines for driving dynamos and alternators, from the first one made in 1884 by the Hon. Charles A. Parsons, C.B., F.R.S., of 10 horse-power to the great ones of up to 8,000 horse-power used in the great power stations of Carville, Neasden, Chelsea, Paris, &c.

He then described the further development of the steam turbine for driving rotary air-compressors of the turbine type now largely used for blowing blast furnaces and other work, and pointed out the advantages gained of light weight, small foundations, small consumption of oil, and, above all, high economy of steam. These are generally for about 20,000 cubic feet free air per minute and a pressure of 10 to 15 lb. per square inch. A slightly different type is also made for about 30,000 cubic feet air per minute at about 1 lb. per square inch pressure, which are used in several large ironworks and elsewhere for dealing with the waste gases from furnaces and driving these gases through the recovering plant, &c., an important point being that they do not clog with tar and other matters.

Since it is almost, if not quite, impossible to utilise economically low-pressure steam at about atmospheric pressure in a reciprocating engine, the exhaust steam turbine becomes of importance in many cases where there are non-condensing

¹ Published in *Engineering*, August, 17, 1906.

² Published in the *Electrical Review*, August 10 and 17, 1906.

engines and other sources of exhaust steam. Several such installations are described and the high economy attained by such turbines is explained.

As a steam turbine can utilise the highest vacuum attainable to its full extent, the use of the vacuum augmentor described in a paper before the Institution of Civil Engineers read in December 1905 is given, with some instances of the high vacua obtained in practice by its help.

In conclusion the marine turbine was briefly touched on, and the great development from the little 'Turbinia' of 1897 to the gigantic Cunard express liners of to-day was described.

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3. *An Application of Stream Line Apparatus to the Determination of the Directions and Approximate Magnitudes of the Principal Stresses in certain portions of the Structure of Ships.*¹ By J. SMITH.

4. *On the Teaching of Mechanics.*² By C. E. ASHFORD, M.A.

Brief description of the conditions governing the teaching of mechanics in the new scheme of naval training, consequent on cadets receiving an engineering training in workshops and lecture-rooms concurrently with a scientific and general education in laboratories and class-rooms during four years from the age of thirteen.

The result of this close co-operation of the schoolmaster with the engineer is to prevent the teaching of mechanics from becoming academic on the one hand, or rule of thumb on the other.

School science is seriously in danger of becoming as academic as classics, largely from the influence of the Universities, which train the masters, and from the preponderance originally given to chemistry. So far as mechanics was taught, it was taken originally by the mathematicians as a pure effort of the imagination and mathematical reasoning powers. Even now the physics master, where he exists, has not sufficiently broken away from these lines. Mechanics is quite rightly used to gild the pill of mathematics and to give reality to that subject; but no one in a school is able by his training to provide the necessary counterpoise of actuality. Science masters have been trained on toys and models, and on taking up teaching find their laboratories fitted with them; if they have to arrange courses of mechanics, they are accustomed to deal with scientific instrument makers (who supply only models often more costly than the real thing). Often they do not know where to obtain actual machines, like screw-jacks and Weston's blocks, which are better for both lecture-room and laboratory. The technical school avoids this fault, but often lacks the good influence of the rigorous mathematician and the trained educationist.

The ideal system seems to be to combine under one roof the skilled engineer, the science master, and the schoolmaster experienced in giving a wide general and literary education, and to carry on their teaching simultaneously for a period long enough to allow each to give what he considers essential.

Another difficulty in the school teaching of mechanics is the present lack of experimental apparatus for showing the phenomena of kinetics. This has been met by Mr. W. C. Fletcher's recent adaptation of the trolley to this purpose, together with the work since done by many teachers. Some examples in this direction, as well as other pieces of apparatus, which have been designed by the staff of the Royal Naval College, Dartmouth, may be of interest. Among others the following will be described and illustrated:—

Trolleys adapted to illustrate Newton's Second Law of Motion, the conservation of linear momentum (including recoil of a gun), to demonstrate the transformation of potential into kinetic energy, to investigate the laws of rotation about

¹ Published in *Engineering*, September 28, 1906.

² Published in *School World*, September 1906.

an axis, including measurement of moment of inertia and moment of momentum, and to study the composition of accelerations and S.H.M. Also apparatus to measure the range of a projectile, the back pressure of a jet of water, the meta-centric height of a ship model, and the horse-power transmitted by a propeller shaft.

WEDNESDAY, AUGUST 8.

The following Papers were read:—

1. *The Central Technical College Lecture Table Testing Machine.*¹
By PROFESSOR ASHCROFT.

2. *The Strength and Behaviour of Ductile Materials under Combined Stress.* By WALTER A. SCOBLE.

In former tests of ductile materials under combined stress, either the ultimate strength has been considered or the tensions have been applied so that the distribution was approximately uniform. The experiments were made on bars subjected to bending and twisting to reproduce the irregular distribution of stress occurring in practice, and the yield-point was selected as the criterion of strength. The bars were $\frac{3}{4}$ inch diameter and 30 inches effective length. The critical bending moment was found to be greater than the yield torque, 2,660 and 2,400 lb. in. and plotting the corresponding bending and twisting moments an ellipse gave the closest approximation to the results. With both loads on there was simultaneous yielding in both ways. The maximum principal stress varied considerably, the maximum shear stress being nearly constant. The results, and those of other experiments, were analysed to determine if the variation of the maximum shear stress was due to a force analogous to friction, or the reverse, proportional to the force perpendicular to the plane of maximum shear. This was found not to be so, the variation in the values of the maximum shear stress probably being due to differences in the shear strength in various directions.

3. *Recent Advances in our Knowledge of Radiation Phenomena, and their Bearing on the Optical Measurement of Temperature.*² By J. B. HENDERSON.

4. *Electro-positive Coatings for the Protection of Iron and Steel from Corrosion.*³ By S. COWPER-COLES.

5. *Suction Gas Engine Plants.*⁴
By PROFESSOR W. E. DALBY, M.A., M.Inst.C.E.

6. *Waterproof Roads as a Solution of the Dust Problem.*
By DOUGLAS MACKENZIE.
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¹ Published in *Engineering*, August 24, 1906.

² Published in the *Electrician*, August 17, 1906.

³ Published in the *Engineering Times*.

⁴ Published in *Engineering*, August 10, 1906.

SECTION H.—ANTHROPOLOGY.

PRESIDENT OF THE SECTION—E. SIDNEY HARTLAND, F.S.A.

THURSDAY, AUGUST 2.

The President delivered the following Address:—

A FRENCH anthropologist lately reviewing two works, one by an Englishman and the other by a German, on the Masai, remarked that, speaking generally, English and German observers, while applying the same methods of observation and making use of the same *questionnaires*, do not interest themselves equally or in the same way in the social life of peoples in the lower culture; for whereas the German explorers by preference describe, and that with praiseworthy minuteness, the nature of the country and the material civilisation of the people, the English, on the other hand, interest themselves more in the intellectual products, the traditions and beliefs. In other words, he said, the German is more of an ethnographer, the Englishman is more of a student of folklore and psychologist. I am not disposed to contest this expression of opinion. To me there is an element of extreme fascination in the attempt to trace the course of human thought on the great subjects of life and death, of mind and matter, in the endeavour to mount again to the source and beginning of speculation, by means of careful observation and comparison of the ideas, and their expression in word and deed, of races as yet guiltless of elaborate philosophical systems, races to which writing, and therefore literature, are unknown. It is beyond question, moreover, that the problems of savage religion and savage philosophy, and their relation to the early history of the human species, have during the last thirty or forty years taken a deep hold of the imagination and occupied the attention of English anthropologists and philosophical writers. This is, perhaps, owing in part to the seriousness with which as a nation we take our religion, and which has led in other fields to Ritual Commissions and to bitter controversy over our elementary schools. In part, however, it is due to the impetus given by the greatest of my predecessors in this chair by the publication of his book on *Primitive Culture* at a time when the public mind was slowly settling to the acceptance of Darwin's teaching. From that hour to the present there has been no pause in the investigations. One champion has overthrown the pretty philological theories of Professor Max Müller, and quenched the Sun Myth in everlasting night. The researches of another, adopting and greatly developing the conclusions of Mannhardt, who had rebelled against the same theories in Germany, have proved to be among the most stimulating influences in anthropological study, both in this country and abroad. Other scholars have applied the same principles in different ways to different subjects. Whether their particular conclusions are right or wrong, they have borne witness to the unflinching interest of the problems; and by the discussions they have aroused they have helped to clear away misconceptions, and have contributed, often materially, to the ultimate solution of the questions at issue.

The religious practices of savage and barbarous peoples are based, as we now know, upon ideas which we have agreed to group together under the general name of Animism. Animism, indeed, is, to quote Professor Tylor, 'the groundwork of the philosophy of religion, from that of savages up to that of civilised man.' As he uses the word it expresses the doctrine which attributes a living and often a separable soul—a soul in any case distinct from the body—alike to human beings, to the lower animals and plants, and even to inanimate objects. But this doctrine is itself derived from a simpler and earlier conception, whereby man attributes to all the objects of external nature life and personality. In other words, the external world is first interpreted by the savage thinker in the terms of his own consciousness; animism, or the distinction of soul and body, is a development necessitated by subsequent observation and the train of reasoning which that observation awakens.

Primitive man is so far away from us, not merely in time, but in thought, that we find it difficult to imagine his attempts to grapple with the interpretation of external phenomena. What waves of wonder, of awe, of terror, of hope, of curiosity, of desire, of bewilderment must have rolled through the sluggish dawn of his intellect! As he struggled in his little communities (little indeed by comparison with ours) with the evolution of speech, how did those various and perhaps ill-defined emotions come to utterance? He was not naturally speculative. Savage man even now is not, as a rule, speculative, though observers who have had opportunities of comparison have noted great differences in this respect between one people and another. Everything primitive man saw, everything he heard or felt, must have struck his mind primarily in its relation to himself—or rather to the community, the food-group, of which the individual formed a part, to its dangers and its needs. The personal element dominated his thoughts, and must have found expression in his words. As a matter of fact, it forms everywhere the basis of language. Hence it was impossible for man to interpret external phenomena in any other than personal terms. This necessity may have been an inheritance from a pre-human stage, since there is reason to think that the lower animals project their own sensations to other animals, and even to objects without life. Yet to fix the objective personalities that primitive man thought he saw and felt about him must have taken time and observation. Not all objects claimed his attention in the same degree or with the same insistence. Some would stand out aggressively, would fill him with a sense of mystery, or of power manifested in ways that seemed analogous with his own. Others would long remain comparatively unregarded until something happened which awakened his interest. His attitude was first of all and intensely practical, not contemplative. His fellow-men, the animals he hunted, the trees whose branches he saw waving in the breeze, the sun and moon overhead going their daily rounds—to all these he would early attach significance: they would easily yield the personal quality. But what of the pools, the hills, the rocks, and so forth? There must have been many things that long abode in the twilight of indeterminate conceptions. The North American Indian lays a tribute of tobacco at the foot of any strange rock whose form strikes him as he passes, or strews his gift upon the waters of the lake or stream that bears his canoe. It may be that his earliest forefather who set the example of such an offering did so without any definite conception of a personality behind the phenomenon, but, smitten by fear or awe, simply sought, by the means familiar to him in the case of known personal beings, to conciliate whatever power might lurk beneath an unwonted form. And although a comparatively definite conception of a personality might in time crystallise, to be transformed later by the philosophy of animism into the idea of a spirit, yet there must always have remained, after all these crystallisations, the vague and formless Unknown, confronted in all its more prominent manifestations through the medium of an undefined dread of power which might yet be revealed from it.

In this relation of the personal and the impersonal lies, I believe, the secret of primitive philosophy, if philosophy it may be called, all unreflective as it must have been. There is no written record of man's earliest guesses at the meaning of the universe. Whatever they were, they were limited to his immediate surround-

ings and the relation of these surroundings to himself. We must judge of them as they are represented in the beliefs and actions of modern savages and in those of great historical nations. For we are all agreed that the history of the human mind has been that of a slow evolution from something lower than the lowest savagery known to-day, that it has not everywhere evolved in the same way or to the same degree, and that the course it has taken has left traces, discoverable by close inspection, upon every mental product and in every civilisation throughout the world. The records on which we have to rely in the investigation are of the most various value, and often most difficult of interpretation, relating as they do to subjects which cannot be reduced within the terms of any mathematical formula, and dependent as they are upon the uncertainties of human testimony. I need not trouble you with a general defence of the evidence upon which anthropological facts repose. After all criticisms have been made there remains a solid body of evidence from which we may confidently reason. What can we learn from it on the point under discussion?

The first thing I want you to notice is the fluidity of the savage concept of personality. It is not confined within the bounds of one stable and (if I may so say) unchangeable body. You and I may quite easily be transformed into something more than metaphorical representatives of the British Ass. Your next-door neighbour, for whom you have the profoundest respect as a prosperous man of business and a churchwarden of exemplary piety, may startle you some morning with a sudden change into a noisy little street-arab, not a tenth of his own portly dimensions, turning a wheel all down his garden path, or into a melancholy cow cropping a bare pittance of grass from his closely trimmed lawn. He and his magnificent wife may even become, like Philemon and Baucis, an oak and a lime tree before your eyes, or a pair of standing stones upon the moor. None of these metamorphoses would be accounted impossible by peoples in the lower culture. The personality which they have known running in one mould can, in their opinion, be directed into and will run as freely in another mould, and yet be the same. So hard do such archaic beliefs die, that in remote parts of our own country it is still firmly believed that a witch may assume the form of a hare, and if any bold sportsman succeed in wounding it, the injury will afterwards be found on the witch's proper person, testifying beyond dispute to the preservation of her individuality under the change of shape and species.

Shape-shifting, as it is called, may even take place by means of death and a new birth without loss of identity. Miss Kingsley tells us that in West Africa 'the new babies as they arrive in the family are shown a selection of small articles belonging to deceased members whose souls are still absent: the thing the child catches hold of identifies him. "Why, he's Uncle John; see! he knows his own pipe;" or, "That's Cousin Emma; see! she knows her market calabash," and so on.'¹ This belief and corresponding practices are found over a large part of the world. Nor is it necessary that the deceased should be born again in human form, or even of the same sex. A Mongolian tale relates that a certain Khotogait prince, having been beheaded for conspiracy against the Chinese emperor, twice reappeared as a child of the empress, and was identified by the cicatrice on his neck. Both children were successively destroyed, and he was then born as a hairless bay mare, whose hide is still preserved. In the same way, fish, fruit, worms, stones, any object, indeed, may, if it can once (no matter how) enter the body of a woman, be born again and become human. This is surely implied by the legends of supernatural birth and the practices corresponding therewith for the purpose of obtaining children—legends and practices found over the whole earth. As developed by animism, the doctrine of a new birth has become what we know as that of the Transmigration of Souls, which has played a part in more religions than one. But from the beginning it was not so, for animism was unknown.

Moreover, detached portions of the person, as locks of hair, parings of finger-nails, and so forth, are not dead, inert matter. They are still endowed with the life of their original owner. Nay, garments once worn, or other objects which have

¹ *Travels in West Africa*, p. 493.

been in intimate contact with a human being, are penetrated by his personality; remain, as it were, united with him for good or ill. The cleft ash through which a child has been drawn for the cure of infantile hernia, bound up and allowed to grow together, continues to sympathise with him in health and sickness as though part of his own body. In the same way, in the Polynesian islands, red feathers of the man-of-war bird, for which the gods were supposed to have special favour, were introduced into or attached to the images of the gods. To anyone who brought fresh feathers a small bundle of such as had been previously deposited was given in return. It was first placed before the image from which it had been taken. The priest prayed to the god, requesting him to abide in the feathers. Then, declaring that it was inhabited (that is to say, by the god in question), he delivered it to the person who had brought the fresh feathers, by whom it was carried home and deposited in a bamboo cane, to be taken out and addressed in prayer from time to time. If prosperity attended its owner, that prosperity was attributed to the feathers. They were honoured with an image, into which they were wrought, and possibly, at a later date, with an altar and a rude temple. But when they were attached to the new image it was taken to the old temple, 'that the supreme idols might sanction the transfer of their influence.'¹ This is the reason given by the missionary Ellis, whose account I have summarised. I think we must infer that not merely the influence, but a portion of the personality of the god himself, had passed into the feathers, and that while his chief home was at the great temple where his chief image dwelt, he was also present whithersoever the bunches of feathers, which had been consecrated by deposition upon or within it, had been carried.

Such beliefs as these are well known, and it would be waste of time to multiply examples. They exhibit a concept of personality imperfectly crystallised. It is still fluid and vague, only to become entirely definite under the influence of trained reason and a wider and more scientific knowledge. But, such as it is, there is behind and around it the still vaguer and unlimited territory of the Impersonal, because the Unknown. Every object that is known has its own personality—every object, whether living or, according to our ideas, not-living. What remains is the stuff out of which personalities are formed as it is gradually reduced into definite relations with the savage observer. These personalities do not necessarily correspond to anything objective. They may be creations of the excited imagination. It is sufficient for the savage that they seem to be and to have a relation to himself which he cannot otherwise interpret. His emancipation from this state of mind is gradual. It leaves its traces everywhere—there most of all where emotion is most acute and permanent, where hopes and fears are most overwhelming, in the sphere of religion.

Now, every personality is endowed with qualities which enable it to persist, to influence others, and even to overcome, subjugate and destroy them for its own ends. No more than ourselves could the primeval savage avoid being influenced and often overmatched by the charm and wiles of woman, the wisdom of the elders of his tribe, the dauntless might of the warrior. The non-human personalities with which he came in contact possessed qualities not less remarkable than those of the human. The strength, the fierceness, the agility of the lion, the speed of the antelope, the cunning of the fox, the lofty forms and endurance of the forest trees, their response to every breath of wind, and the kindly shelter they yielded to birds and beasts and men, the fantastic forms and stern patience of the rocks, the smooth and smiling treachery of the lake, the gentle murmur and benign largess of the river, the splendour, the burning heat of the sun, the changeableness and movement of the clouds, are qualities, a few of the more obvious, attached to the myriad personalities with which men found themselves environed. These personalities and their qualities would impress them all the more because of the mystery that perpetually masked them, mystery through which only on rare occasions or to favoured human beings they deigned to speak directly in the language of mankind. Mystery magnified them, and magnified

¹ Ellis, *Polynesian Researches*, vol. i. p. 338.

all their qualities. Hence every non-human personality was conceived in larger than human terms, and its qualities were larger than human.

Not merely was every personality, human and other, endowed with qualities, but by virtue of those qualities it possessed a potentiality and an atmosphere of its own. The successful warrior and huntsman by more than his successes, by his confidence and his brag, his readiness to quarrel, and his vindictiveness, or the many-wintered elder, wise and slow to wrath, experienced in war and forestry, of far-reaching purpose and subtle in execution, would be enshrined in a belief in his powers, surrounded with a halo of which we still see a dim, a very dim, reflection in the touching regard entertained for a political leader or the worship paid to an ecclesiastical dignitary. Nor would this atmosphere surround only important or successful men. Everyone is conscious of powers of some sort, and everyone would attribute to others capabilities larger or smaller. Some would possess in their own consciousness and in the eyes of their fellows a very small modicum of power for good or evil. The mere glance or voice of others would inspire terror or confidence. This potentiality, this atmosphere, would often cling with greater intensity to non-human beings, objective or imaginary. The snake, the bird, the elephant, the sun, the invisible wind, the unknown wielder of the lightning, would be richly endowed. None, human or non-human, would (in theory at least) be wholly without it.

The Iroquoian tribes of North America possess a word which exactly expresses this potentiality, this atmosphere, which they believe inheres in and surrounds every personality. They call it *orenda*. A fine hunter is one whose *orenda* is fine, superior in quality. When he is successful he is said to baffle or thwart the *orenda* of the quarry; when unsuccessful, the game is said to have foiled or out-matched his *orenda*. A person who defeats another in a game of skill or chance is said to overcome his *orenda*. 'At public games or contests of skill or endurance, or of swiftness of foot, where clan is pitted against clan, phratry against phratry, tribe against tribe, or nation against nation, the shamans—men reputed to possess powerful *orenda*—are employed for hire by the opposing parties respectively to exercise their *orenda* to thwart or overcome that of their antagonists, and thus secure victory. So, when a storm is brewing, it (the storm-maker) is said to be preparing its *orenda*; when it is ready to burst, it has finished, has prepared its *orenda*. Similar expressions are used for a man or one of the lower animals when in a rage. A prophet or soothsayer is one who habitually puts forth his *orenda*, and has thereby learned the secrets of the future. The *orenda* of shy birds and other animals which it is difficult to ensnare or kill is said to be acute or sensitive—that is, in detecting the presence of the hunter, whether man or beast. Anything reputed or believed to have been instrumental in obtaining some good or accomplishing some end is said to possess *orenda*. Of one who, it is believed, has died from witchcraft it is said, 'An evil *orenda* has struck him.'¹

Equivalent expressions are used by a large number of American tribes. The same general idea is found elsewhere. 'The Melanesian mind,' says Dr. Codrington, 'is entirely possessed by the belief in a supernatural power or influence, called almost universally *mana*. This is what works to effect everything which is beyond the ordinary power of men, outside the common processes of nature; it is present in the atmosphere of life, attaches itself to persons and to things, and is manifested by results which can only be ascribed to its operation.' And again: 'It is a power or influence not physical, and in a way supernatural; but it shows itself in physical force, or in any kind of power or excellence which a man possesses. This *mana* is not fixed in anything, and can be conveyed in almost anything; but spirits, whether disembodied souls or supernatural beings, have it and can impart it; and it essentially belongs to personal beings to originate it, though it may act through the medium of water, or a stone, or a bone.'² The idea of *mana* seems to differ from that of *orenda* in that, according to Dr. Codrington, it does not belong to all men, and is rather a special than universal characteristic of

¹ J. N. B. Hewitt, in *American Anthropologist*, N.S., vol. iv. p. 38.

² Codrington, *The Melanesians*, p. 118.

personalities ; but there can be no doubt, I think, that the two ideas are essentially the same, and that that of *mana* has become more limited by appropriation. An important step has thus been taken by the Melanesian mind towards differentiating between human and superhuman attributes and potentialities.

Although the idea of *orenda*, or *mana*, may not receive everywhere the same explicit recognition, it is implied in the customs and beliefs of mankind throughout the world. It underlies the practice of Taboo. When a Malagasy sticks up in his field a figure or scarecrow to keep off robbers, it is not that they may dread prosecution with all the rigour of the law, though that, perhaps, will be the result if they are caught. What is threatened is sickness, mysteriously induced by the power of the owner of the field, or by power which he has caused to be conjured into the scarecrow.¹ A Samoan in the same way suspends to a cocoa-nut palm a small figure of a shark, made with the leaves of the tree ; it is notice to the robber that he will be inevitably devoured by a shark.² The Siberian Chukchi, whose fire has gone out on the cold and timberless tundra, cannot borrow fire from his neighbour, for 'the fire of a strange family is regarded as infectious and as harbouring strange spirits. Fear of pollution extends also to all objects belonging to a strange hearth, to the skins of the tent and the sleeping-room, and even to the keepers and worshippers of strange penates. The Chukchi from far inland, who travel but little, when they come to a strange territory fear to sleep in tents or to eat meat cooked on a strange fire, preferring to sleep in the open air and to subsist on their own scant food supply. On the other hand, an unknown traveller, coming unexpectedly to a Chukchi camp, can hardly gain admittance to a tent, a difficulty of which the writer I am here quoting had personal experience.³ It is, of course, impossible to discuss the subject of taboo in detail. Suffice it to say that the universal avoidance of a dead body, the taboos of women, the taboos observed by priests, by chiefs, by hunters and warriors, the taboos of temple and shrine, of times and seasons, of speech and act, may all be traced to the same root-idea. Our words *sanctity*, *pollution*, *infection* feebly and partially translate the intuitive dread of *orenda* which is embodied in a taboo.

Take, again, the Evil Eye as a striking example of *orenda* which has survived into civilised communities. Here the whole maleficent potentiality of a person is concentrated in a glance ; and the amulets which are worn on the body, or suspended on the wall, or at the door of a house, are directed to intercepting and so exhausting the influence. What foundation there may be for the modern psychological doctrine of Telepathy it is not my business to determine. But I should like to point out its resemblance to the Iroquoian doctrine of *orenda*. Telepathic communication may result from conscious or unconscious exertion of will ; it may occur at a supreme crisis of fate or at a casual moment ; it is, in either case, the product of a potentiality which we call *mystic* for want of a better name, and which attaches to or flows from some personalities more strongly than others. We are all conscious of occasionally meeting, or receiving a letter from, someone on whom our thoughts have been more or less insistently dwelling, and whom we do not expect immediately to see or to hear from. Goethe is reported by his friend Eckermann as having told him : 'I have often enough had the experience in my youthful years of a powerful longing for a beloved maiden taking possession of me during a lonely walk ; and I thought about her and thought about her until she really came and met me.' We need, however, no such commonplace illustration to convince us of Goethe's *orenda*.

Now, without multiplying illustrations which will spring to the mind of every anthropologist, it seems to me that in this potentiality, this atmosphere, this *orenda*, *mana*, call it by what name you will, we have the common root of magic and of religion. He for whom the world is full of personal beings, and hardly anything else—a universe of objects interpreted in the terms of conscious personality and projected on a background of the Unknown with all its possibilities—

¹ Van Gennep, *Tabou et Totémisme à Madagascar*, p. 184.

² *Ibid.*, p. 185, note. Cf. Codrington, *op. cit.*, p. 215.

³ W. Bogoras, in *Amer. Anthropol.*, vol. iii. p. 97.

he for whom each of those objects, human and non-human, living and not-living, is invested in a greater or less degree with *orenda*, will naturally and instinctively on the one hand avail himself of his own *orenda*, and on the other hand will dread and endeavour to turn to account the *orenda* of others. But this very endeavour to turn others' *orenda* to account is an exercise by prayer or compulsion of his own. I can see no satisfactory evidence that early man entertained any great faith in the order and uniformity of nature. The personal will and *orenda* of himself or some other object were the origin of all causation. If he took aim at his enemy and flung his spear, or whatever primitive weapon served the same purpose; if it hit the man, and he fell; he might witness the result, but the mere mechanical causation, however inevitable in its action, would be the last thing he would think about. Conscious of his own will, of his own effort, of the words, perhaps, with which he had accompanied and directed the spear, he would attribute the result to such causes as these. His own *orenda* felt in his passion, his will, his effort, and displayed in his acts and words, the *orenda* of the spear, either inherent in itself, conceived as a personal being, or conferred by its maker, and manifested in the keenness of its point, the precision and the force with which it flies to its work and inflicts the deadly wound—these would be to him the true causes of his enemy's fall. His *orenda* is mightier than his enemy's, and overcomes it. So, when the enemy is absent and he cannot visibly reach him, his *orenda* may yet suffice to inflict the desired injury. By a psychological process which Mr. Marett has acutely analysed he is led to perform in pantomime all the acts of murder in the absence of the victim, either silently or to the accompaniment of a chant or of spoken words. His foe, who is as convinced as himself of the power of such a performance, if it come to his knowledge, falls a victim to the terror it inspires, unless he can call in the aid of some other person, objective or imaginary, whose *orenda* is more powerful still. Nor would the belief lack vindication even in the case of the victim's ignorance; for any chance misfortune or sickness would be put down to a hostile *orenda*; and if he did escape, it would be due to his own superior *orenda*.

Thus magic is primarily an application of *orenda*. By his *orenda* a man bewitches his enemy (or, for a consideration, someone else's enemy), causes rain or sunshine, raises and protects the crops, gives success in hunting, divines the cause of sickness and cures it, raises the dead, spells out the future. His incantations, his gestures, his apparatus—whether of plants, stones, animal products, magical drawings or moulded figures, or whatever else it may be—would be of no avail without this. In Central Australia the Arunta magician arms his 'pointing bone' with *arungquilha*. In Central Africa the Murundi wizard impregnates his magical implements with evil influence by means of his imprecations, his incantations and his evocation of spirits. That is, he puts into them his *orenda* or the *orenda* of the spirits: until then they are absolutely powerless and indifferent.¹ This influence, this *orenda* or *arungquilha*, is the *nexus*—the copula, as it has been called—which links the subject, the magician, to the object, the result. But man is not the only being who possesses *orenda*. The *orenda* of his quarry sometimes foils his own. The cicada chirping in the field ripens the maize for the Iroquois; the *orenda* of the rabbit controls the snow and fixes the depth to which it must fall. The awful mountain, the treacherous sea, those mighty beings who command the winds, who send forth the storm, who rule in the darkness and mystery of the forest, possess an *orenda* surpassing man's. It is useless to pit his *orenda* against theirs. Therefore he must adopt a different course. He must lay down his *orenda* and submit it to theirs. This is the literal meaning of the Iroquoian phrase which signifies in modern usage 'He habitually prays,' expressive of an habitual attitude of humility towards the higher powers.² He must take such a course as he would take to obtain assistance from a human being (say, a powerful chief) or to conciliate an enemy. By gift, by abasement, by abstinence, by self-torture, by cajolery he must win this powerful *orenda* to his side. Of these efforts abstinence

¹ J. M. M. van der Burgt, *Un Grand Peuple de l'Afrique Equatoriale*, p. 55.

² Hewitt, *op. cit.*, p. 40.

and abasement are negative forms of propitiation. They are perhaps the earliest forms. If our reports be complete (on which we may have our doubts), abstinence is the only form used among the Andaman Islanders, where belief outruns active worship.¹ In any case, a taboo for propitiatory purposes is very early and very persistent. Not without insight does the poet tell us that Caliban

‘Will let those quails fly, will not eat this month
One little mass of whelks, so he may ’scape.’

And the modern European has still his Lent and his Fridays throughout the year. Such abstinence is the laying down and submission of the *orenda* to those of mightier beings. On the other hand, gift, prayer, cajolery are, properly speaking, an active exercise of *orenda*. Spell and incantation are often indistinguishable from prayer. They shade into one another by the finest gradations. More than one comparatively civilised people has held that sacrifices properly performed not merely incline, but compel, the gods to grant what their worshipper desires. Gesture-language, as I need not remind you, plays a large part in savage life. A ceremony such as those familiar to us in sympathetic and mimetic magic often is, to a large extent, gesture-language: it helps to suggest to the mighty beings of whose *orenda* the magician desires to make use exactly what is wanted. It is more than this, of course. It is in part the make-believe which is a relief to over-charged feelings; in part it is the means by which the *orenda* is conveyed to the desired object. The words which accompany and form part of the ceremony emphasise the desire. They fill and strengthen the instrument with the *orenda* of the performer, or of the being invoked or compelled to assist; they direct the instrument, considered as a personal being, in the part which it is required to take; or they allure, entreat, or command the object at which the rite is aimed.

If the view I have taken be accurate, the essential opposition between magic and religion disappears. Nor am I greatly concerned to decide whether of the two developed the earlier. Their origin is the same; they grow from one root. ‘By whatever name it is called,’ says Dr. Codrington, speaking of the Melanesian *mana*, ‘it is the belief in this supernatural power and in the efficacy of the various means by which spirits and ghosts can be induced to exercise it for the benefit of men that is the foundation of the rites and practices which can be called religious: and it is from the same belief that everything which may be called magic and witchcraft draws its origin.’ ‘All Melanesian religion consists, in fact,’ he says elsewhere, ‘in getting this *mana* for one’s self, or getting it used for one’s benefit—all religion, that is, as far as religious practices go, prayers and sacrifices.’ ‘Wizards, doctors, weather-mongers, prophets, diviners, dreamers, all alike, everywhere in the islands, work by this power. There are many of these who may be said to exercise their art as a profession; they get their property and influence in this way. Every considerable village or settlement is sure to have someone who can control the weather and the waves, someone who knows how to treat sickness, someone who can work mischief with various charms. There may be one whose skill extends to all these branches; but generally one man knows how to do one thing and one another. This various knowledge is handed down from father to son, from uncle to sister’s son [for the people of these islands have not yet emerged from the stage of mother-right], in the same way as is the knowledge of the rites and methods of sacrifice and prayer; and very often the same man who knows the sacrifice knows also the making of the weather and of charms for many purposes besides. But as there is no order of priests, there is also no order of magicians or medicine-men. Almost every man of consideration knows how to approach some ghost or spirit, and has some secret of occult practices. Knowledge of either kind can be bought if the possessor chooses to impart it to any other than the heirs of whatever he has besides.’² Here we see the beginnings of the professional magician and the professional priest. The professional magician is he who in the course of the evolution of society, by birth,

¹ E. H. Man in *Journ. Anthropol. Inst.*, vol. xii. pp. 161, 163, 353, &c.

² Codrington, *op. cit.*, pp. 192, 119.

by purchase, or by study and practice in the conventional methods, has acquired the most powerful *orenda*. Similarly, the professional priest is he who in these ways, or by prayer and fasting, has acquired the favour of the imaginary personalities believed to influence or control the affairs of men—who has, in a word, possessed himself of their *orenda*. The union of these two professions in one person is not adventitious; it is probably fundamental; it is at least so general that in describing the society of savages and peoples in low stages of culture observers are often at a loss whether to call their functionaries priests, or wizards, or medicine-men. Consequently the custom has arisen among anthropological writers of using the word *shaman*, borrowed from some of the Siberian tribes, and including all three meanings. For in that condition of society the functions of priest and sorcerer and medicine-man are, as Dr. Frazer says, 'not yet differentiated from each other.' We of course are familiar with the distinction between magic and religion. As society evolved, according to Spencer's famous formula, from an indefinite, incoherent homogeneity towards a definite, coherent heterogeneity, step by step religion became severed from magic. Yet it has never become so wholly severed that the primitive connection may not be traced. Priests have become organised into a separate order. Triumphant religions have proscribed the conquered faiths, and have repudiated their practices as magical. The conquered faiths under this repression have carried on their religious worship mixed with magical rites, and tending more and more to be degraded into pure magic, yet never losing all religious elements. Even the magic of the Middle Ages, and later, in Europe, if we may trust the confessions of the judicial victims themselves, was mingled with the worship of a being in whom they recognised the devil, perhaps the last avatar of a heathen god; and witchcraft was one of the commonest charges against heretics. On the other hand, not even the highest religions have been able to free themselves wholly from what are in effect magical rites, by which their followers have striven to compass union with the objects of worship, to possess themselves of their *orenda*, to locate it in their own persons or in the images and implements of their cult, to intensify their own *orenda*, and to exercise it for the benefit, spiritual, corporal or pecuniary, of themselves and others.

The sketch which I have thus tried to draw embodies what seem to me to be the results of the latest inquiries and discussions on a subject still obscure. I do not pretend it is complete. I do not pretend it is original. And I must of course admit that it is a speculation. We can never obtain direct evidence as to what took place in that archaic period when man had only just begun to be man and had hardly reached even the bottom rung of the ladder of civilisation. That is matter of inference—of guesswork perhaps—but the guesswork of one who has to fit together the scattered and disordered pieces of a puzzle. In putting our puzzle together we have to assemble and classify our facts, and whatever guess (or let us dignify it by the name of theory) colligates the facts in the most satisfactory manner—that is likely to be nearest the actual truth.

I may be told that I have ignored whole series of facts—prominent among them the customs and superstitions of the Arunta, that tiresome people of Central Australia who have made hay of so many beautiful anthropological theories. Well, I do not know what other series of facts I have ignored, but I have been considering the question all the time with one eye fixed on the Arunta and their neighbours. The Arunta have been represented to be the lowest and least evolved of known humanity in their beliefs and institutions: in a word, they are in the stage of primitive atheism from which it is said we have all been developed. Now none of the Australian tribes are, strictly speaking, in a primitive condition. The civilisation of all of them has evolved to some extent. It has evolved, speaking in general terms, along similar lines; and these lines have been conditioned by the environment. It is admittedly significant that, in a land where so many archaic types of the lower animals have survived we should find archaic types of human culture. The environment and the isolation of ages have in both cases preserved them. Yet the most archaic types of Australian culture are far from being primitive. So far are they that the social organisation is of a most complex character, the product of a long succession of stages of development. The least archaic types

exhibit the old social organisation breaking down and new structures in course of formation. With the evolution of society an evolution of belief has also been going on. It has not been exactly concurrent. Culture rarely or never evolves equally in all directions. It is a mental process, partly conscious, partly unconscious. The common mind of a given society, like the individual minds of which it is composed, is not exercised equally on all subjects at the same time. Hence while, for example, we find among the Euahlayi tribe, in the north of New South Wales, a more advanced theology and a more developed worship than have been recorded elsewhere in Australia, the social organisation is still on the basis of female descent, and though the clansmen eat without scruple their hereditary totems, in other respects the totemic system seems to be in full force.¹ In the same way the Arunta and their neighbours certainly preserve relics of a very archaic condition of thought and social organisation. Though for certain purposes a son inherits from his mother's husband, they recognise very imperfectly the physical relation between father and child. They have no tribal chiefs, no social hierarchy. On the other hand, they have developed a very elaborate theory of reincarnation, and their totemic system is in course of transformation into a number of societies for magical purposes bearing in some respects remarkable resemblance to those of the tribes of British Columbia. Magical practices are more prominent than what we are usually accustomed to associate with the name of religion. Yet a closer examination will lead us to the conclusion that religion, albeit of a low type, is not wholly wanting. I am by no means satisfied that Twanyirika, the bugbear 'to frighten babes withal,' is this and nothing more. Adjacent tribes sharing the general culture of the Arunta at all events believe in the real existence of a superior being called by that or some other name, whom they fear, and in obedience to whom they perform the rites of initiation. When, at the close of these rites amongst the Arunta, someone with a bundle of *churinga* in his hand comes up to the newly initiated youth, saying, 'Here is Twanyirika, of whom you have heard so much; they are Churinga and will help to heal you quickly,'² neither the neophyte nor his friend regards them as mere toys. The statement that they will help to heal the neophyte's wounds is enough to show this. We must not be misled by the apparent anticlimax to forget that they are mysterious objects, in the closest association with the tribal ancestors, the outward and visible sign, if not the embodiment, of the ancestral souls or invisible portions, and as such regarded with veneration. They are endowed with *mana*, emanating from the ancestors whom they represent—*mana*, which in the belief of these tribes not merely heals wounds, but when the *churinga* are brought ceremonially in contact with the body produces other physical, mental and even moral effects. Among the Kaitish, the performance of some ceremonies, in the course of which the *churinga* are handled, renders a man so full of this *mana* that he becomes for the time taboo. More than this, the *churinga* make the yams and the grass-seed to grow; they frighten the game or enable a man to secure it, and so forth. They are handled in a manner which it is no exaggeration to call devout. They are polished with red ochre to 'soften' them, a term which, as Messrs. Spencer and Gillen remark, 'very evidently points to the fact that the [*churinga*] is regarded as something much more than a piece of wood or stone. It is intimately associated with the ancestor, and has "feelings," just as human beings have, which can be soothed by the rubbing in the same way in which those of living men can be.' We gather that a man will sing to his *churinga*, that the subject of his song will be the mythical story of the ancestor (or rather the previous incarnation) to whom it belonged, and that as he sings and rubs it with his hand he 'gradually comes to feel that there is some special association between him and the sacred object—that a virtue of some kind passes from it to him, and also from him to it.'³ Found on another continent these *churinga* would have been called fetishes in well-nigh the most extended meaning of that word. It is plain that the beliefs and rites of the natives of Central Australia cannot be circumscribed by the limits of the term Magic.

¹ Mrs. Langloh Parker, *The Euahlayi Tribe*, passim.

² Spencer and Gillen, *Central Tribes*, p. 249. Note also the threat which follows.

³ *Ibid.*, *Northern Tribes*, chap. viii. passim.

Magic, like religion, is difficult to define. Many have been the attempts, more or less successful, to analyse and define both, and I have no intention to add to them. But if magic be held to be something in origin and essence distinct and separate from religion, something parallel with modern science in its faith in the order and uniformity of Nature, and only to be distinguished from it by its false application of the principles of association; if whenever it invokes the aid of spirits it is no longer pure, but alloyed with religion; then it must be seriously asked whether pure magic ever occurs, and, if so, where. For, like religion, it is founded, as I have tried to point out, on the primitive interpretation of man's environment in the terms of his own consciousness; and that interpretation is not scientific, but anthropomorphic. It is that interpretation which gives its value to the spell. The spell implies the personality of the objects to which it is addressed. The Arunta sings in his Intichiuma rites. He invites the witchetty grubs to come from all directions and lay their eggs, or the Hakea trees to flower and their blossoms to fill with honey. He chants of the increase in the number of the kangaroos which he is endeavouring to secure. Even when the songs recall transactions in the Alcheringa they are not necessarily more magical than the words of sacred dramas, which everywhere in the lower culture inseparably interweave magic and religion. The mighty ancestors (as elsewhere the gods) are present in the rite, either attached to the churinga or in their reincarnations; and where invitation or command is not issued directly to the object, the *mana* of the ancestors seems to be invoked for the accomplishment of the end.

Again, so far from the Arunta medicine-men being practitioners of anything analogous to modern science, they are initiated by, and their power is derived from, the spirits. These spirits are believed to put the candidate to death, to carry him down into the other world, and there to take out his internal organs, replacing them with a new set, planting in his body a supply of magical crystals by which all his subsequent wonders will be performed, and then bringing him to life again. It is true that an imitation of this process can be performed by medicine-men of flesh and blood; but candidates thus initiated have a lower repute than those initiated directly by the spirits.¹ The crystals are in any case the home and symbols of the magician's powers. They are, in fact, full of *mana*. If they be lost the magician ceases to be a magician. All over Australia, so far as we know, the same influence is attributed to them. On the eastern side of the continent, where something like a tribal All-Father is believed in, he is regarded, like Odin, as the mightiest of magicians, and the crystals are, as well as the bull-roarer or churinga, among his special attributes. Let me observe, too, in passing that it is not a little significant that, as in the witchcraft of Europe and Africa, portions of dead bodies are in great request in Australia for magical purposes. The 'pointing bone,' to which I referred just now, is part of a dead man's leg or arm. A portion of his personality inheres in it; consequently, even before it is 'sung,' it is endowed with his *mana*, which the singing only enhances. For the same reason human fat and a dead man's hair are important parts of the Australian native's magical apparatus.

The initiation of the medicine-man by spirits, often the spirits of the dead, is practically the universal belief in Australia. In this respect the Australian medicine-man, or shaman, is in line with his brethren all over the world. The Andaman Islanders are, perhaps, at a lower stage of civilisation than the Australian blackfellows. According to our accounts, which are probably imperfect, magic is little developed among them. Their shamans are called by a word signifying dreamer. In dreams they communicate with 'the invisible powers of good and evil,' they see the spirits of the departed and of those who are sick; and the beginning of what we may call their professional life is 'an extraordinary dream,' in which future events are revealed to them.² In Siberia, the Gilyak shamans are chosen vessels, to whom their tutelary gods reveal their high calling in vision or in trance. From the moment that this is done the gods instal themselves as the new

¹ Spencer and Gillen, *Central Tribes*, p. 522.

² E. H. Man in *Journ. Anthropol. Inst.*, vol. xii. p. 96.

shaman's assistants and perform his commands. Yet shamanhood is not regarded as a gift, but as a burden. To become a shaman, either a man must find favour with one of these assistant tutelary gods, or such a god must be bestowed upon him by his father or uncle. Conversion into a shaman forms a break in the life of the chosen, accompanied by many complicated psychological phenomena. The process in his own case was described by a shaman to a Russian anthropologist. For more than two months he was sick and lay without movement or consciousness. As soon as he revived from one attack he fell under another. 'I should have died,' he said, 'if I had not become a shaman.' He began to dream at night that he sang shaman songs. Visions appeared to him, and he was told to make a drum and the proper apparatus of a shaman, and to sing. If he were a simple man, the vision told him, nothing would happen; 'but if thou art a shaman, be a real shaman.' When he awoke he found that it was thought the spirits had killed him, and preparations for his funeral rites had been made. But he got a drum and began to sing. This produced a feeling which hovered between intoxication and death. Then for the first time he saw his tutelary gods, and received from them instructions in his business as a shaman.¹ Among the Chukchi, also, the shaman is chosen by the spirits, and a similar method of initiation is pursued by them.² In South Africa, the Zulu or Xosa who aspires to become a witch-doctor distinguishes himself by dreams and visions, and begins to talk of his intercourse with the spirits of the dead. He often behaves as if he were out of his mind. He 'becomes a house of dreams;' he is possessed by an Itongo. Then he is admitted to the society of other wizards and receives instruction from them. Finally he is accounted a new creature, whose intercourse with spirits and share in their supernatural power is recognised by everyone.³ The Ojibway sorcerer, after prolonged fasting, is initiated by the supernatural powers.⁴

Among the Sea Dyaks of Borneo 'there are two descriptions of *manangs* [shamans], the regular and the irregular. The regular are those who have been called to that vocation by dreams, and to whom the spirits have revealed themselves. The irregular are self-created and without a familiar spirit.' It is not enough for the *manang* simply to 'say that he feels himself called; he must prove to his friends that he is able to commune with the spirits; and in proof of this he will occasionally abstain from food and indulge in trances, from which he will awake with all the tokens of one possessed by a devil, foaming at the mouth and talking incoherently.'⁵ One of the ways to 'get magic' among the Malays is to meet the ghost of a murdered man. In order to do this a ceremony must be performed at the grave on a Tuesday at full moon. The aspirant calls upon the deceased for help, and states his request. Ultimately an aged man appears, to whom the request is repeated; and it would seem that he gets what he wants.⁶

The records of witchcraft in Europe are full of stories of initiation, which begin by the formal renunciation of Christian worship and baptism. The novice tramples upon symbols of the Christian faith, or otherwise treats them with indignity; he utters incantations with appropriate rites to call up the devil; finally that gentleman appears to receive his formal profession of allegiance, admit him ceremonially into his band of worshippers, and tutor him in the methods of his art. Down to this day, indeed, in many Continental countries, if not in the British Islands, the peasant witch enters upon her trade by a ceremony which recalls the main features of this initiation.

It would be easy to expand the list. Enough has, however, been said to show that at all stages of civilisation now to be found in the world, save where magic is a mere attenuated survival, what we call supernatural beings are concerned with the initiation of the magician, and that the Arunta beliefs do not differ in

¹ *Archiv für Religionswissenschaft*, vol. viii. pp. 463, 467.

² *Amer. Anthropol.* N.S., vol. iii. p. 98.

³ Merensky, *Beiträge zur Kenntniss Süd-Afrikas*, p. 135; Shooter, *Kafirs of Natal*, p. 191; Callaway, *Religious System*, p. 259.

⁴ Peter Jones, *Ojibway Indians*, p. 269.

⁵ Roth, *Natives of Saravak*, vol. i. p. 266.

⁶ Skeat, *Malay Magic*, p. 60.

this respect from those current elsewhere. It is not my intention to discuss the psychological and physiological aspects of the phenomena. They recall the phenomena of 'conversion' among ourselves. Occurring, as they usually do, at or shortly after the commencement of adult life, they display the effervescence of puberty, accentuated by the neurotic peculiarities of the individual, acted upon, directed and controlled by the social environment. Of the social side of religion and magic I have said little. In these days, when individualism is so strongly developed in thought and action, we are apt to forget to what an extent religion is an expression of the social organisation. An eminent professor, lately deceased, used to say that religion was a social secretion. That may be an excellent way to phrase the relations between society and religion in modern Europe. It is a very incomplete account of them as they exist on the Australian steppe or in the forests of Brazil. In societies which have yet but imperfectly advanced from the indefinite, incoherent, homogeneous condition religion is much more than a social secretion: it is one aspect of the inchoate organisation. Every member has his place and takes his share in religious rites. Every member is on the same level of knowledge and belief. The mental atmosphere is charged with the same electric fluid, which communicates itself to all alike. Its action is thus intensified. Pervading every thought and deed, both of the individual and of the community, it binds the members together as no other force could do. The slavery of men in the lower culture to custom is a commonplace of anthropology. That custom is religious to the core. It has regard to the superhuman helpers and the superhuman foes of the community, as well as of the individual. Everyone observes it, because upon it depends the weal of all alike. Moreover, everyone's eye is upon his neighbour, and a departure from custom is sure to be resented as something sinister. At this stage magic is not yet severed from religion. The same rites, the same practices, the same course of daily conduct appeal to superhuman helpers and bespeak the exercise of their *orenda*, and at the same time endeavour to exercise in the traditional manner the *orenda* of the performers. Departure from them, otherwise than with the consent of the community, is viewed with suspicion and concern. At the very least, and done innocently, it will bring misfortune on the doer and all connected with him. Done with a purpose, it is abhorred and punished as evil magic. It is this kind of magic, performed with anti-social objects, which alone is reprobated in the lower culture. Death is very generally regarded as unnatural. If not caused by open violence, it must be due to magic. Hence at every death an inquest is held to ascertain who is responsible; the accused is required to undergo an ordeal, and is punished if found guilty, as he usually is. But it is not the practice of magic which is condemned; it is the application of magic to the injury of a member of the community—that is, to the injury of the community. A Zulu chief 'smells out' and puts to death the witch who has slain his father. The same chief habitually practises magic on another chief before fighting with him, and employs his own wizard to make rain. His sacrifices and acts of worship are inextricably mingled with magic. The schism between magic and religion is a later development of civilisation. Even then, as the history of heresy in Europe and the witch-trials teach us, it is rather magic in its anti-social aspect than in itself which is reprobated and punished. The departure from established custom and established belief involves a severance from the community and an imputation of anti-social ends. The pursuit of individual desires and hatreds at odds with the general interest is what arouses the anger of society. Practices essentially magical may be incorporated in religious rites and exercised for what is believed to be the general good, and they will continue to be exercised with general assent even in the highest forms of religion.

Do you ask me to speculate further, to forecast the future, to consider whether religion will ever free itself from magic, whether the bond of religion will still be necessary to hold society together? These are questions of the highest interest; but my *orenda*, such as it is, does not extend to prophecy. If it did, they are not questions within the scope of the British Association, Section H. My aim has been simply to set before you the present position, as I conceive it, of research on

the absorbing subject of the origin and relations of religion and magic. I do not know whether I have succeeded in satisfactorily synthesising the results of the inquiries of a generation of students. Nor can I forget that the inquiries now in progress, and those which an unknown future has in store, may ere long change our point of view and suggest fresh and yet unthought-of solutions of the problem.¹

The following Papers and Report were read:—

1. *Notes on the Ethnography of the Ba-Yaka.*² By T. A. JOYCE, M.A.,
and E. TORDAY.

The Ba-Yaka are a tribe inhabiting a district on the Kwango and Inzia Rivers, tributaries of the Kasai, in the Congo Free State. From their culture, which exhibits most of the characteristics distinctive of the primitive West African type, they appear to be closely connected with the tribes on their southern and western borders. The men are rather small, but well-built and good-looking. They eat almost any flesh, except that of dogs, but the women are forbidden to eat fowls and eggs. They do not practise cannibalism. Agriculture is conducted by the women. Their crafts comprise weaving, pottery-making, and metallurgy. Stone implements are not found, neither is there any tradition of their use. Huts are rectangular, and the villages are small. Marriage is the result of purchase. Children belong to the village of their mother, to which they are sent as soon as they can walk. The tribe is ruled by a paramount chief, but each village has a petty chief, which office is hereditary. The chief currency is shells. Slavery is universal. The people have numerals up to eleven, and for 100, 1,000, and 10,000. They are fond of music. An interesting musical instrument is the *reibtrommel*, a very specialised form of instrument which has an extremely limited distribution in Africa. Justice is administered by assemblies, and every crime, except treason, can be compensated for by a money payment. Every adult male is a warrior. The only weapon is the bow and arrow, although imported swords are found. Circumcision is practised. The dead are painted red and buried in a sitting position, clothed, but without weapons. Pots are broken in the grave. The people believe that the soul leaves the body at death and visits the living in dreams. In the case of important persons it is believed that the soul enters the body of large animals.

2. *The Aborigines of Sungei Ujong.*² By F. W. KNOCKER.

The people discussed in this paper were the wild tribes inhabiting the hills to the north and north-west of the State of Negri Sembilan. Commonly called Orang Bukit (People of the Hills), they assert that they are either connected with Sakai tribes or are of Sakai origin. They call themselves *Orang Berlanus* or *Orang Bersisi*. In stature the Orang Bukit are short, but they are well

¹ In connection with the questions touched upon in the foregoing address I desire to call special attention to the following works:—

J. G. Frazer, D.C.L., *The Golden Bough*, 2nd ed., vol. i. pp. 60–80. London, 1900.

R. R. Marett, 'Preanimistic Religion,' in *Folk-lore*, vol. xi. pp. 162–182; 'From Spell to Prayer,' in *Folk-lore*, vol. xv. pp. 132–165.

J. N. B. Hewitt, 'Orenda and a Definition of Religion,' in *American Anthropologist*, N.S., vol. iv. pp. 33–46.

H. Hubert et M. Mauss, 'Esquisse d'une théorie générale de la Magie,' in *L'Année Sociologique*, vol. vii. Paris, 1904.

M. Mauss, *L'Origine des Pouvoirs Magiques dans les Sociétés Australiennes*. Paris, 1904.

L. R. Farnell, D.Litt., *The Evolution of Religion*. London, 1905.

T. H. Preuss, 'Der Ursprung der Religion und Kunst,' series of articles in *Globus*, vols. lxxxvi., lxxxvii. (1904, 1905).

² To be published in full in *Journ. Anthropol. Inst.*

and solidly built. Their hair is black and thick, their eyes dark brown, and their faces wedge-shaped. The profile is negroid and there is no prognathism. They are intellectual and bright, and live moral and blameless lives. There are no ceremonies or rites to celebrate birth, marriage, or death. They have no religion nor belief in a spiritual existence after death, nor do they practise any form of witchcraft or magic. They have a system of chieftainship. The original clothing of these people was nothing more than a bark loin-cloth, but they now wear clothes procured from the Malays and Chinese. Their only indigenous weapon is the blow-pipe, through which they shoot poisoned darts. They possess both percussion and wind musical instruments, and follow agricultural pursuits, most of which they have learnt from the Malays. They cannot count beyond three.

3. *On the Bushmen of Basutoland.* By S. S. DORNAN.

The Dutch on arrival in South Africa found races of diminutive people occupying the ranges of mountains near Cape Town. They were afterwards found far to the north, and Moshesh found them in Basutoland when he occupied the country about 1820. The principal migrations to Basutoland occurred after the Great Trek of 1836. There were two parties: the first party lived at Hermon, near Wepener, and were known as Bushmen of Mamantso; they were tall and strong; they left Hermon and went to Little Caledon, where they stole cattle from Moshesh, were driven north to Teyateyaneng, and eventually retired with other clans to Griqualand East. The second party, known as Bushmen of Uphaki, went south to Quthing. When driven out they divided into two bands, and went up opposite banks of the Orange River. The principal leader was Swai, whose fate extinguished the Bushmen as a nation in Basutoland. The place-names in that part of the country are due to these bands. The last remnant also retired to Griqualand East.

The few Bushmen left in Basutoland are mostly half-breeds. They are very unwilling to talk of the past, and the Basuto dislike any attempt to glean information of their past history. They have had no influence on the physique of other races. Their language was difficult and peculiar, abounded in clicks, of which traces persist in Sesuto and more extensively in Kafir. They are called Baroa by the Basuto, Abatwa by the Kafirs, San by themselves. The Bushman government was family, not tribal, and they lived mostly in caves. They were partly monogamous, partly polygamous. Loose family relations prevailed. Cattle were no inducement to polygamy as in other races.

Their food was mostly game, supplemented by roots dug up with the qibi or digging-stick, and grass seeds. Little pottery was made. The paintings in their dwelling-caves are very numerous; the colours used are mostly black and brown.

They called the storm spirit Qeng; believed in witchcraft, but did not practise 'smelling' out. They marked the places where they buried their dead with a small cairn of stones.

Bushman place-names are very numerous in Basutoland, but the signification of most is unknown.

Their extinction was principally caused by their inability to change their mode of life; but a war of extermination was carried on by both Bantu and Europeans.

4. *Marriage and Mating.* By S. S. BUCKMAN, F.G.S.

The ancestors of *Homo* and of the anthropoid apes must have started equal at some remote period. Why has *Homo* become dominant and world-wide, while the anthropoids are so few? The argument is that man has succeeded because he remained in a social community in which jealousy in sexual matters was so feeble as not to break up the herd, while the anthropoid apes have failed because

extreme jealousy—the development of individualism in sexual affairs—broke the herd into small hostile single-male groups.

It is contended that among *Homo* sexual relationship, similar to that of a social herd, *e.g.*, the seal, obtained. But it is objected that the terms promiscuity or communal marriage applied to these relationships are misleading, so special technical terms are introduced to define the relationships, while ordinary terms are limited in this wise: Mating is when the female is always free to choose her partner; marriage where she is the property of the male by the law of might, by custom, or otherwise, and cannot leave at will; rape when she is forced to submit; and communal rape, the action of victorious warriors to captive women.

Consideration is then given to the arguments of Mr. Lang and Dr. Westermarck against the idea that man was socialistic and free-mating in his early days. Mr. Lang's idea that communal mating meant communal suckling is shown to be an erroneous deduction, because it only occurs in exceptional circumstances—death of offspring, and consequent milk-troubles. Dr. Westermarck's idea about the enforcement of pre-nuptial chastity is met by argument that this is a taboo custom, indicative, therefore, of pre-nuptial unchastity.

A theory of the evolution of marriage is then given—that it has not arisen from the free mating of social animals, because with them the female was, for physiological reasons, too sparing in her acceptance. This did not satisfy the overwhelming lust of the human male; therefore the males banded together and raided other tribes, stole their women, and made them submit or be killed. So, not content with conquering all other species, man conquered the female half of his own. He carried the females away as his slaves or wives; and it is out of the practice of communal rape that marriage has arisen.

5. *Eighth Report on the Lake Village at Glastonbury.*—See Reports, p. 410.

6. *The Ethnology of South Africa.* By Dr. A. C. HADDON, *F.R.S.*

FRIDAY, AUGUST 3.

The following Papers and Report were read:—

1. *Exhibit of Bronze Weapons and Implements from Persia.* By Major P. MOLESWORTH SYKES, *C.M.G.*

2. *Note on Major Sykes's Collection.*¹ By Rev. Canon GREENWELL.

The objects were discovered near Khinaman, in South-east Persia. They were associated, as grave goods, with unburnt burials. No similar cemetery has yet been met with in Persia. The discovery is of the utmost interest, not only from the nature of the articles, but from the light thrown upon the early metallic stage of culture in the country.

The find consists of five bowls, two pins, two javelin-heads, two armlets of ordinary penannular form, two rods with curved ends, possibly symbols of authority (two knives, one with a tang, the other very thin and oval in shape), and two axe-heads. All these objects were of bronze. Besides these two clay vases of globular form were found and some very large pottery vessels, too big to bring home. The axe-heads are the most interesting part of the find. They were not weapons, as the manner of fastening the handles precludes such a possibility; but they were either representative weapons made for burying with the dead or were

¹ To be published in *Journ. Anthropol. Inst.*

for ceremonial use. They are double-ended. The second has, in addition to the ornament common to both, two animal figures, one standing over the top of the socket, and the other, a lion, standing in the curve of the sharp end.

3. *Note on the Webster Ruin, Rhodesia.*¹ By E. M. ANDREWS.

This ruin is situated on a kopje in the South Melssetter district, about sixty miles south of the township of Melssetter. The ruin is unique, being situated within a sacred enclosure containing a large number of graves. The building is not circular, although it was probably meant to be. It rises in two tiers to a dome or small tower. The stones are carefully laid and form a decided batter—no mortar is used nor any attempt at bonding made. The entrance, on the west side, is rounded. The steps are large flat stones, and come out on the top a little to the south of the dome. Two monoliths are in front of the entrance, and beyond these are two more, and beyond again one monolith. These three sets of monoliths are apparently to guard the entrance. One of the large flat stones at the foot of the monoliths has the 'Fuba' board cut on it. Among the graves stand other monoliths. The graves face in all directions, but were not examined. The building seems to be a royal tomb, and is apparently of greater age than other ruins in Rhodesia.

4. *The Origin of the Guitar and Fiddle.* By Professor RIDGEWAY, F.B.A.

It has been long recognised that various stringed instruments have been developed out of the shooting-bow—*e.g.*, the harp of the North and the Greek lyre of the conventional shape—but no full explanation of the shape of the body of the guitar and the fiddle seems yet to have been given.

The peoples north of the Alps had originally no instrument with a sounding-board, for the addition of the latter to the harp came late. Thus the harp of the north and the *kithara*, which Apollo is fabled to have brought with him from the land of the Hyperboreans, are both simple adaptations of the primitive bow. On the other hand, Greek legend says that Hermes, the indigenous god of Arcadia, mollified the anger of the Northern Apollo by presenting him with a *chelys*, which Hermes himself had manufactured out of the shell of a tortoise, from which the instrument took its name (*chelys*). That such an instrument existed in Greece is no myth, for Pausanias (*circ.* A.D. 180) says that in Arcadia there are tortoises of large size, as well adapted as the Indian tortoises for making lyres. In the tortoise-shell of southern lands Nature had furnished man with a natural sounding-board, whereas in northern lands none was ready to hand. The instruments with sounding-boards are, therefore, the product of the South. Guitars made of tortoise-shell are still commonly used in certain parts of the Mediterranean basin; *e.g.*, the specimens shown, one from Algeria, the other from North-west Morocco. In addition to the tortoise-shell, Nature has supplied other natural sounding-boards in Africa, *e.g.*, the gourd. Hence most African instruments have sounding-boards, not only the banjo and mandolin, but also more elaborate forms, such as the marimba of Loanda. Now, whilst the banjo, mandolin, and bomba clearly arose from the addition of a gourd as sounding-board to the primitive shooting-bow, in the waist of the guitar and fiddle of South Europe we have a distinct development from the slight narrowing or waist to be seen in the shell of the tortoise. Accordingly, then, the characteristic instruments of South European lands owe their distinctive form to the fact that man in that region had at hand the tortoise-shell with its peculiar conformation.

¹ To be published in *Man*.

5. *Report on Archaeological and Ethnological Researches in Crete.*
See Reports, p. 408.

6. *Excavations at Sparta in 1906.* By R. C. BOSANQUET, *M.A., F.S.A.*

The work of the British School at Sparta in 1906 has been to survey the site and investigate the Romano-Byzantine fortress. Parts of the Hellenic town-wall have been discovered and traced, and general conclusions have been formed as to the extent and disposition of the town at different periods.

The sanctuary of Artemis Orthia has been identified and the stratification of a 'geometric' and a 'Corinthian' layer determined. Extensive deposits of ivories, lead figurines, and grotesque clay masks have been found, the last affording evidence as to naturalism in archaic Spartan art; in Roman times there was a further development of the cult, and numerous votive inscriptions recording musical and athletic victories of Spartan boys in the second century A.D. have been found. In the third century A.D. a theatre-like building was constructed in the *τέμενος*, the proscenium of which was the front of the temple.

Besides the Director of the School, Messrs. R. M. Dawkins, G. Dickins, H. J. W. Tillyard, Ramsay Traquair (architect), and A. J. B. Wace took part in the campaign. The complete excavation of the Temple of Artemis will require at least another season.

7. *Note on the Prehistoric Civilisation of South Italy, with special reference to Campania.* By T. E. PEET, *B.A.*

The author discussed Professor Pigorini's interpretation of Dr. Quagliati's discovery (in 1899) of a well-marked *terramare* settlement at Scoglio del Tonno, near Taranto (*Tarentum*).

A survey of the offshoots of the Villanovan culture on both sides of the Apennines suggests (1) that on the eastern slope the influence of this culture, though it extended past Novilara to the valleys of the Pescara and Sangro, failed altogether to penetrate into Apulia, obstructed apparently by the representatives of the 'Apulian' culture of the Early Iron Age; (2) that up the valleys above named the Novilara culture *did* extend south and westward as far as Alfidena and the head-waters of the Volturno, and so came into contact with the Campanian culture, but only late, in the relation of borrower rather than lender; (3) that the culture of Campania, though based, like that of Novilara, on the lineal descendant of the æneolithic culture of Middle Italy, derived its Villanovan elements from the north by way of Latium, but transmuted them so completely that it is as difficult to believe that a Villanovan culture, supposed by Pigorini to have existed in South Italy, passed southward by way of Campania as to suppose that it penetrated by the Adriatic slope of Italy.

It follows that Scoglio del Tonno must be regarded as the result of an isolated raid of *terramare* folk, not as the representative of any widespread culture of 'Italic' type.

8. *On the Evolution of Design in Greek and Turkish Embroideries.*
By MISS L. F. PESEL.

The material on which this paper is based has been collected and studied in Greek lands round the shores of the Ægean. The embroideries themselves are of very different ages and styles; the only early-dated specimen belongs to 1760, but the designs show the influence of Byzantine art, modified by contact with Italian art both of the Middle Ages and of the Renaissance, and also with Oriental styles brought from Asia Minor and other parts of the Turkish Empire, and even from as far off as Persia.

Endeavours are now being made to collect and classify, before it is too late, the examples of the principal styles, basing inferences on those kinds of which

the place of manufacture is certain, and having regard to material, colours, workmanship (*e.g.*, stitches), design, and the original use of the embroidered object.

The establishment of an accepted terminology of fabrics and designs must not be expected until more work has been done in detail, but provisionally the author distinguishes groups which may be designated as 'Rhodian,' 'Cretan,' 'Turkish,' with subdivisions corresponding with the territories, such as those of the old Duchy of Naxos and Cyprus, in which the Italian influences above named are especially marked, or in which, as in the North Ægean, 'Oriental' traits predominate. The use of vague popular terms, such as the 'style of Janina,' is to be deprecated. The principal varieties of style were illustrated by photographs of typical examples.

MONDAY, AUGUST 6.

The following Papers and Reports were read:—

1. *On the 'Red Hills' of the East Coast Salt Marshes.*

By F. W. RUDLER, I.S.O., F.G.S., and W. H. DALTON, F.G.S.

The 'red hills' are low mounds of burnt earth, thickly scattered along parts of the estuarine marshes of Essex and other East Coast counties. Probably Roman if not pre-Roman in date, their crude pottery, their relative position to the present tide-levels, waterways, and coast-line, and their other characteristic features, have given rise to much controversy as to their age and original purpose. A brief account of these interesting relics was read to the Association in 1880 by the late Mr. Henry Stopes ('Transactions,' 1880, p. 631), and they have been described by Mr. W. Cole. Systematic study is now contemplated by a Committee of the Essex Archæological Society, in co-operation with the Essex Field Club.

2. *Archæological Discovery at Gargas.*¹ By Dr. E. CARTAILHAC.

In the Grotto of Gargas hands painted in red have been discovered comparable with similar painted hands found in caves in Australia, which were painted by the Aborigines as records of alliances, &c. The hand was placed flat on the rock and red paint blown round it; the hand was then raised and the imprint left behind on the rock. The Gargas hands have been made in a similar way. Similar hands have been observed in California. At Gargas left hands predominate; some are isolated, some in groups; sometimes they are black. MM. Cartailhac and Breuil have been studying these paintings by the aid of comparative ethnology and will shortly publish their results, which promise to be of great interest in the history of art.

3. *A Winter's Work on the Ipswich Palæolithic Site.*²

By Miss NINA FRANCES LAYARD.

Satisfactory results have been obtained from another winter's work on the Ipswich Palæolithic site. Fifty-four definitely formed implements have been found, besides several dozens of small size showing signs of human work, but of rougher construction. These small tools are of two kinds, but are found associated together. They may be described as respectively adapted for scraping and skinning, and have a certain resemblance to the Neolithic implements employed in this work, though not so carefully finished. Some of the scrapers are roughly squared, but they are by no means uniform in shape. Most show the bulb of percussion on the

¹ Published in *Man*.

² To be published in *Journ. Anthropol. Inst.*

under side, and on the upper side one edge only is worked down. They are a trifle larger than the Neolithic thumb-scraper, and are not so thick in proportion. Strewn among them a number of small flat sharp-edged flakes were found, many of which, when not quite flat enough for the work for which they were intended, had been reduced to the desired shape by a few deliberate blows. These appear to be the knives used in skinning. In all, forty-six scrapers and thirty-three knives were picked up at depths varying from 10 to 12 feet. The author is inclined to recognise in these small implements the Palæolithic prototypes of the later thumb-scrapers, and in the flat sharp-edged flints the forerunners of the Neolithic knives.

One or two points in the geology of the pit which the winter's work brought to light may be worthy of notice. Working in a southerly direction, the brick-earth dividing the upper from the lower flint-bearing gravels was seen to be thinning out till it ended in a tongue of clay, beyond which the gravels were united. The finding of this junction of the gravels appears to be of importance in determining the age of the tools. It might have been supposed that the true depth of the lower Palæolithic bed was 12 to 14 feet; that an enormous interval then ensued during which the thick band of clay was deposited; and that another Palæolithic gravel bed of much later date and quite distinct from the first was then laid down over it. It now appears possible that some of the flints from the surface were swept into a pool in the river bed; that when the rush of water ceased the mud had time to settle down over them, while later another spate brought down gravels and flints from the same original level, and laid them horizontally over the silted-up pool. This would account for the occurrence of tools similar in type in both upper and lower gravels; and it would therefore be correct to say that the site should take its date, not from the lowest level at which flints occurred, but from the highest position in which they were found—namely, $5\frac{1}{2}$ feet only from the present surface.

4 *An Anglo-Saxon Cemetery in Ipswich.* By Miss NINA FRANCES LAYARD.

During extensive works being carried on in Ipswich last winter the author discovered that the high land which was being levelled was the site of an Anglo-Saxon cemetery. In all thirty-three graves were found, from which the following relics were obtained: Eleven spearheads, eighteen knives, eight bosses of shields; seven necklaces of beads, one necklace composed of an iron ring with fastening, on which is one amber bead; three cruciform fibulæ, one circular fibula set with gems and shell; two flat circular fibulæ, one plain, the other ornamented with dots and circles; one large ornamental buckle in three parts, two small buckles, one iron key (Roman pattern), one double-toothed comb, one iron pot-hook, one object of iron and silver, use unknown, two brownish-black pots, two glass drinking-cups of an amber colour, one iron ornament with cable pattern, &c.

Among the six fibulæ found two are worthy of special notice. The large cruciform brooch is interesting as having a stud on the bow—a type rarely met with in England. Another brooch, which is circular in form and of the Kentish type, is of exceptional value. It is of bronze, gilded, and set with garnets and shell. In the centre is a boss surrounded by cable ornamentation, in which a fine ruby-coloured garnet is set in shell, to which the verdigris has imparted a pale-blue shade. With one exception, this is probably the only brooch of the kind which has been found with the centre perfect. One of the small flat circular fibulæ shows remnants of the garments which it fastened still adhering to it. As these are seen on both sides of the brooch, it proves that it was used to fasten an undergarment. This appears to have been of a loosely woven, plaited pattern, while above was a dress, also of coarse material, but of closer make, with the threads running crosswise.

In many cases it was noticed that the chin and neck bones of the skeletons were stained with verdigris, showing that in these cases the brooch was placed beneath the chin.

The flat circular brooches which have no catch show, perhaps, the most primi-

tive method of fastening with a pin. After the pin has been passed through the dress it is brought up over the opposite rim, the natural spring of the metal causing it to hold.

5. *Excavations in an Anglo-Saxon Cemetery near South Cave, Yorkshire.*
By T. SHEPPARD, F.G.S.

During excavations recently made in an Anglian cemetery in East Yorkshire a number of skeletons were found, accompanying one of which was an exceptionally fine series of bronze ornaments, &c. The skeleton was that of a female, lying on the chest, with the hands crossed under the body and the legs slightly drawn up. The various objects found with the skeleton are interesting from their excellent state of preservation, and from the fact that they were obviously new when interred, and had not been previously worn to any extent. Around the neck were a number of amber and glass beads variously ornamented, two flat bronze rings, probably annular fibulæ; and a fine bronze cruciform brooch, $4\frac{1}{2}$ inches in length and $2\frac{1}{2}$ inches in width. At the waist was a collection, including two bronze square-headed fibulæ, almost identical in character, measuring $5\frac{1}{2}$ inches by $3\frac{3}{4}$ inches each; a pair of chatelains or girdle-hangers in bronze, two pairs of bronze clasps, evidently belonging to a belt; and a ring-brooch. The last named is made from the corona or ring of bone at the base of the antler of a red deer, the acus or pin being of iron. In an adjoining grave (containing a male skeleton) a small sax, a knife, spear, and ring—all of iron—were found. The specimens above described were exhibited at the meeting.

6. *Note on some Roman and other Remains from South Ferriby.*
By T. SHEPPARD, F.G.S.

A somewhat eccentric collector known as Tom Smith, or 'Coin Tommy,' recently died at South Ferriby, on the South Humber shore, and his collection was sold. Most of the specimens were secured for the Hull Museum, including over 3,000 coins, nearly 100 fibulæ of various types, rings, beads, buckles, keys, &c., mostly in bronze. Some of the fibulæ are enamelled. In addition to the smaller ornaments, &c., there is a quantity of domestic pottery, including dishes, basins, strainers, mortaria, &c. There are a few pieces of Samian ware, some of which bear the potter's marks. In association with the objects enumerated were found some British Neolithic implements and gold and silver coins, as well as Saxon fibulæ and mediæval and later objects. All the specimens were found within about a quarter of a mile of each other, and have been exposed during the last forty years, as the Humber has washed away the cliffs. They were probably from the site of a small Roman camp and cemetery, which unfortunately is now almost washed away.

7. *Pygmy Flints from Yorkshire and Lincolnshire.*
By Rev. R. SCOTT-GATTY.

8. *Report on the Age of Stone Circles.*—See Reports, p. 370.

9. *Report on Excavations on Roman Sites in Britain.*—See Reports, p. 400.

10. *On the Primitive Artemisia of Ephesus and their Contents.*
By D. G. HOGARTH.

11. *Excavations at Caerwent, Monmouthshire, on the Site of the Romano-British City of Venta Silurum in 1904-6.* By T. ASHBY, jun., M.A., D.Litt.

The present excavations at Caerwent, Monmouthshire, began in 1899 and have been carried on every summer since then for a period of about three months. The results obtained up to August 1904 were described in a paper read at the Cambridge Meeting (see p. 339 of the Report). The rest of the season of 1904 was devoted to the exploration of a very large house (known as XII.) on the west edge of the road leading to the south gate, in which three or four different periods of construction could be distinguished. An interesting mosaic pavement was discovered here, which has been removed to the Newport Museum. The house has been filled in again, but a full account has been published in 'Archæologia,' lix. 2.

The beginning of the season of 1905 was devoted to clearing the inner side of the south gate, which was found to have been filled in the same way as the north gate, but with greater care; the inner arch is to a considerable extent still preserved.

The rest of the time was spent in work in the northern half of the city. Five buildings were excavated, one of which, containing an octagonal bath, is probably part of a building situated further north, which may be the public baths of the city. Of the others, one is remarkable for possessing a colonnade, another for having one of its walls preserved to a height of over 12 feet, the lower part retaining considerable remains of painted plaster. Two wells were excavated, and yielded a large quantity of plant remains.

The President of the fund, Lord Tredegar, has generously acquired, for purposes of excavation, a considerable area in the north-east portion of the city, and the campaign of 1906 will probably be devoted to the further examination of several buildings, of which portions only have up till now been accessible.

12. *Recent Excavations in the Roman Forum.* By T. ASHBY, jun., Litt.D.

Among the most striking discoveries in the more recent excavations have been those in the open central area (the Forum proper) and the Comitium. On the boundary between the two a black marble pavement has been found—the representative of the *lapis niger* in the Imperial Age—and below traces of many different periods, which further excavation may elucidate, though partially successful attempts at their interpretation have already been made. They must be connected with the Rostra of the period of the kings and of the republic, while the Rostra of Cæsar are situated at the north-west end of the Forum, it being he who was responsible for the change of orientation which took place. In the open area in the centre the base of the equestrian statue of Domitian, the Lacus Curtius, and an inscription, which, perhaps, leads to the determination of the site of the *tribunal pratorium*, were discovered; while the exact spot where Cæsar's body was burnt has been laid bare.

13. *The Keltic Weights found in a Roman Camp (Melandra, near Glossop).* By Professor R. S. CONWAY, Litt.D.

The Manchester and District Branch of the Classical Association is engaged in the study and excavation of the numerous Roman sites in their part of the country, and in the course of their work at a camp known as Melandra Castle, near Glossop, of which a report has been furnished to this Section, attention has been given to a set of thirty weights found at different times in the camp.¹ Of these some eighteen are certainly or probably of Roman standard. The rest are not Roman at all. An article by Mr. T. May, of Warrington, in the current

¹ See Professor Conway's article on 'The Weights' in Report entitled 'Melandra Castle.' (Manchester Univ. Press, 1906.)

number of the 'Derbyshire Archæological Journal' points out the close approximation of the heaviest specimen to the standard which Mr. Reginald Smith, of the British Museum, had shown to be represented by a bronze weight found at Neath (4,770 grains), and another (of basalt) at Mainz (4,767 grains), and by the normal weight deduced from that of a large number of iron bars found in the purely British lake-village at Glastonbury and in other British sites. Mr. Smith's conclusions entirely establish the soundness of the text in Cæsar, 'B. G.' v. 12, 4: 'Taleis ferreis ad certum pondus examinatis pro nummo.' Details are given by Mr. Smith in his paper on the Ancient British Iron Currency ('Proceedings of the Society of Antiquaries,' xx., 179, January 26, 1905), and in outline in the 'Guide to the Antiquities of the Early Iron Age in the British Museum,' 1905, pp. 149f. Both the Neath and the Mainz specimens exhibit the same cheese or barrel shape which appears in four Melandra specimens (1, 2, 5, 12); each of the two is marked I on the face, but the Mainz specimen has a further legend which no one yet has interpreted, I ∩ followed by a third sign, apparently a Q tilted to the left.

The peculiar importance of the collection at Melandra is that we have here represented certainly seven (including the unit), and quite possibly nine, denominations of this standard, whose subdivisions have been hitherto entirely unknown.

The nature of the subdivisions is also interesting. Besides the duodecimal principle (in Nos. 2, 3, 8, 25, and ?21), following that of the Roman *libra* and *uncia*, to which Mr. May's article calls attention, we must recognise not less clearly the quadratic (Nos. 2, 5, 8, ?12, 20, 28, and ?21), giving us a division of the unit into 4, 8, 16, 32, and ?96 parts. Nos. 2, 3, 5, and 21 could belong to either, and 12 may just conceivably be Roman and represent $10\frac{1}{2}$ drachmæ or seven times the weight of an Antoninianus.

It would, of course, be possible to interpret all these weights as representing so many 'British drachmæ' (if one may coin such a term for the sake of argument), since 96 is a common denominator for both 12 and 16; but one seeks a reason for the creation of weights to represent 6 and 12 'British drachmæ,' i.e. $\frac{1}{16}$ and $\frac{1}{8}$ of the 'British pound' respectively, if there was no other named standard than $\frac{1}{2}$ of the unit ('British uncia') and $\frac{1}{8}$ ('British drachma'). And that there was some other such named unit weighing $\frac{1}{16}$ of this 'British pound' (298.1 grains) seems at least suggested by the markings on Nos. 12 and 20, which would then be the weights of two and one such units respectively; unhappily, No. 12 is nearly 8 per cent. under its proper weight on this hypothesis. It is also clear that the markings on No. 8 vouch for the duodecimal system, as Mr. May points out. But Nos. 20 and 28 are unimpeachable witnesses for the quadratic system.

Can we conjecture from this that we have here the result of the imposition of the Roman system of 12 ounces and 96 drachms upon a Keltic system of dividing the pound into sixteen parts? And that, therefore, the essential characteristic of our modern 'avoirdupois' measure goes back to the Early Iron Age? A similar case of the imposition of Roman divisions upon a local unit occurs at Pompeii; see 'The Mensa Ponderaria of the Naples Museum,' App. I. to my edition of the remains of 'The Italic Dialects.' And examples more important for Northern lands will be found in Appendix C of Professor Ridgeway's 'Origin of Metallic Currency and Weights Standards.'

No. 3, which has been considerably cut about, and does not correspond in shape to No. 2, looks like a Roman weight cut down to the Keltic standard.

It seems as if there must be some connection between this division and the fact that in the *unga* of the Brehon Laws (= 1 Roman *uncia*, or 432 grains) there are 32 crosogs of 13.5 grains (Ridgeway, p. 396). But it is not quite clear whether there is any relation between the actual standards of this Melandra system and the older Irish system, which Professor Ridgeway (p. 406) suggests, of 30 crosogs to an ounce of 405 grains.

Some weights not yet publicly described, but said to correspond to the Neath standard, have recently been found in Somersetshire, and are now in the Castle Museum, Taunton.

TUESDAY, AUGUST 7.

The following Papers were read:—

1. *Demonstration of the Methods of Determining Racial Characters.*
By Dr. F. C. SHRUBSALL.

2. *Exhibit of British Crania in the possession of the Yorkshire Philo-
sophical Society, and of Crania from Lamel Hill, York.* By Dr.
G. A. AUDEN.

3. *Notes on a recently discovered Skeleton in Scoska Cave, Littondale.*
By HAROLD BRODRICK, M.A., and C. A. HILL, M.B., B.A.

Scoska Cave is situated about a mile beyond the village of Arncliffe and at a height of 230 feet above the river Skirfare. The opening of the cave is about 7 feet high and 15 feet wide. At a distance of 250 feet from the entrance the cave branches, the right branch being more than 400 yards in length. The left branch (which contains a small stream) is entered by creeping under a ledge 18 inches high; the roof soon rises to a height of 4 feet, and continues at this level for 400 feet; at this point the roof lowers, and a few yards beyond many bones in a good state of preservation have been found. All the bones belong to one person, and were for the most part almost entirely buried in stalagmite; they were scattered along the floor of the cave over a distance of about 20 feet. The skull is that of a female Celt, being of the brachycephalic type. All the teeth are present, with the exception of the two back molars, which evidently fell out subsequently to death. The teeth show signs of considerable attrition, being worn flat with the loss of the enamel in the molars; this has evidently been caused by eating corn ground between gritstones, the grit being left in the flour. Just above the right mastoid process is a small, irregularly shaped hole, which has penetrated the inner table of the skull and has evidently been the cause of death. The blow would not prove instantly fatal, so that the woman had probably crawled up the cave to die, the position in which the bones were found precluding the idea of burial.

Measurements and Notes.

Skull.—*Length*, 168 mm.; *Breadth*, 138 mm.; *Height*, 129 mm.; *Vertical index*, 76; *Cephalic index*, 82, Brachycephalic; *Cubical capacity*, 1,420 cc., Mesocephalic.

The skull is that of a female, the mastoid processes being small, the frontal sinuses and the superciliary ridges diminutive.

Observations.

Angle of nose almost at right angles to face. Nasal septum deflected to the right. Hypertrophy of the left turbinal bone. Palate high-arched and contracted. Dental margin saddle-shaped.

The junction of the basi-occipital with the sphenoid is obliterated, therefore the skull is that of a person over the age of twenty-four, and as the inter-parietal or sagittal suture shows no signs of commencing obliteration, it is that of one under forty-five.

Tibiae.—Right and left. Length, 355 mm. Female. They have a slight oblique direction downwards and outwards; they are also platycnemic. The tibia in European races is about 22·1 per cent. of the stature; this indicates a height of 5 feet 3 inches.

Humerus.—Left. Length, 316 mm. This indicates a height of 5 feet 2·8 inches.

Radius.—Right. Length, 230 mm. This indicates a height of 5 feet 2·9 inches.

Femur.—Left. Length, 420 mm. Pilastered and compressed in upper part of shaft. General conformation of leg-bones indicates that 'squatting' was the habitual posture when at rest.

4. *On the Relative Stature of the Men with Long Heads, Short Heads, and those with Intermediate Heads, in the Museum at Driffield.* By J. R. MORTIMER.

5. *England before the English.* By J. GRAY, B.Sc.

There is evidence derived from the occurrence of rough stone implements that palæolithic man inhabited England for ages during the interglacial periods of the Ice Age. No skulls of undoubtedly palæolithic man have been found in England. Palæolithic man disappeared from England and from Europe during the end of the Ice Age, and some time after a new variety of the human species—neolithic man—entered Europe. Neolithic man corresponds with the modern Mediterranean race. The Anglo-Saxons, Swedes, and other fair peoples of Northern Europe are apparently a variety of the neolithic race, with somewhat broader heads, which may be due to the selection of an Arctic climate or to a small infusion of a broad-headed race. In the Bronze Age an entirely new race settled in England. This race was brachycephalic and tall, and came by sea to Britain from the Eastern Mediterranean and Asia Minor. The analysis of the measurements of neolithic skulls found in Britain point clearly to the existence of two racial elements in the population of the island.

6. *Discussion on the Physical Characters of the Races of Britain.*

7. *The Hyksos, and other Work of the British School of Archaeology in Egypt.* By Professor W. M. FLINDERS PETRIE, F.R.S.

A great earth-bank camp, twenty miles north of Cairo, proves to belong to the Hyksos, or Shepherd Kings, who held Egypt from about 2400 to 1600 B.C. The camp is about 1,500 feet across, the bank 100 to 200 feet thick, and over 40 feet high. The outside was a great slope of white stucco 60 to 70 feet high, and the entrance was a long slope of over 200 feet ascending over the bank. No such fortification is known before in Egypt. Within a year or two the defenders threw out flanking walls to command the sloping roadway. All of these works are only suitable for archery defence. Two or three generations later, when the stucco face was decayed, an entirely different system was adopted. An immense wall of fine limestone, 45 feet high, 6 feet thick, and over a mile long, was built outside of the bank, which thus ceased to have any slope, and became a walled city. This all accords with Manetho's history, the archers having overcome the Egyptians without a pitched battle, just as the Parthians later destroyed the Roman army. And after a century the Hyksos built a great and mighty wall round their camp of Avaris, which is probably the structure here discovered.

The cemetery of the Hyksos shows that there was a continuous degradation of work in the scarabs during this age. Hence it is possible to begin a systematic arrangement of all the names on Hyksos scarabs, which comprise the greater part of the kings of that race. They appear to have been Semites who came from the region between Syria and Mesopotamia, and they were pushed forward into Egypt and Cyprus by a migratory movement. The full details of this and the following discoveries will be found in 'Hyksos and Israelite Cities,' large edition, the annual volume of the British School.

Other work has brought to view the store city of Raamses, built by the Israelites along with Pithom, and the cemetery of the city of Goshen.

The town and temple built by the high priest Onias has also been found, and

it fully substantiates the accounts given by Josephus about this interesting migration of the Jews into Egypt in the second century B.C.; and a later cemetery at Gheyta shows how Eastern influence was filtering into the country before the great Arab conquest.

WEDNESDAY, AUGUST 8.

The following Papers and Reports were read:—

1. *Early Traces of Human Types in the Ægean.*
By JOHN L. MYRES, M.A., F.S.A.

In spite of the admitted imperfection of the evidence, it seems desirable to attempt certain generalisations from our present information as to the characteristics of early man in Greek lands; at all events, in so far as these may limit the field of profitable inquiry by ruling out hypotheses already indicated as untenable.

I. Broadly speaking, the results of recent work by Virchow, von Luschan, Klon Stephanos, Duckworth, Hawes, and others show that as far back as we have any evidence at all—that is, to the earlier phases of the Bronze Age—we are prohibited from regarding the Ægean as populated by any purely ‘Mediterranean’ type of dolichocephalic man: brachycephalic individuals occur sporadically all over the area of observation. This proof of mixed physique rules out all interpretations of Ægean culture which regard Ægean culture as the exclusive production of unmixed ‘Homo Mediterraneus,’ or regard the so-called ‘Achæan’ irruptions in the centuries from 1500 to 1200 B.C. as the first occupation of Ægean lands by an alien conqueror.

II. The same data as to the presence, and (in the later Bronze Age) the increasing frequency, of brachycephalic types in the Ægean, when compared with the evidence as to the existence of very pure brachycephalic populations in the highland areas east and west of the Ægean depression—*i.e.*, in Balkan lands, and in Anatolia—afford a strong probability, first, that these brachycephalic ‘Alpine’ populations were themselves established in these highlands at least as early as the first phases of the Ægean Bronze Age; and, secondly, that they were in competition with dolichocephalic ‘Mediterranean’ man for the possession of the sunk lands of the Ægean Archipelago. Indeed, while in certain islands the earliest known population is typically dolichocephalic with a mesocephalic ‘margin,’ in others the mesocephalic ‘margin’ accompanies a predominantly brachycephalic type.

III. The circumstance that, as noted by Bogdanov, Sergi, and others, the great lowland steppe region of South Russia, immediately adjacent to the Balkan lands to the north-east, was peopled from neolithic to classical times by a predominantly dolichocephalic population, precludes any assumption that ‘intruders from the north’ into the Ægean must have been brachycephalic: especially in any case in which such intruders can be shown to have retained any traces of a nomad or purely pastoral mode of life. Only where evidence as to complexion is available can dolichocephalic remains in the North Ægean be distinguished into a probably Mediterranean and a probably intrusive group.

IV. The circumstance, already noted, that the highland areas on either side of the Ægean seem to have been occupied by brachycephalic ‘Alpine’ and ‘Armenoid’ populations as far back as our evidence goes makes it extremely improbable that the brunet dolichocephalic type which predominates in the southern Ægean arrived there by any land route, either down the west coast of Greece or along the south coast of Asia Minor, while its brunetness precludes affiliation to the dolichocephalic types of the north. It follows that until some other mode of entry is demonstrated we must regard this type as having entered the Ægean oversea from North Africa. This conclusion is strongly supported by the evidence as to its distribution throughout the Bronze Age, and on into

classical and later times: for it retains throughout its littoral habits, and has never succeeded in penetrating into the interior either of the Balkan lands or of Asia Minor. Ægean culture has spread, but not Ægean man: the Hellenistic peoples of Asia Minor, Macedon, and Epirus are proselytes.

V. Under these circumstances it is reasonable to infer that as far back as we can trace the presence of 'Mediterranean' man in the Ægean, there existed in the Eastern Mediterranean some sort of organised sea-power. The similarity of the earliest Ægean boats with those of early Egypt confirms this view; and the admitted submergence of the habitable foreshore of the Cyrenaica goes far to explain the subsequent unimportance of this once populous area. Egyptian history also affords more than one instance of an aggressive Libyan sea-power, and even of such a sea-power in alliance with admittedly Ægean peoples.

2. *Note on the Ethnology of Sardinia.*

By Dr. T. ASHBY, jun., and D. MACKENZIE.

Like Crete, and for the same reasons, Sardinia would seem to offer very favourable opportunities for craniological and ethnographical research. While the few coast towns have been centres of continuous foreign influence, the remoter mountain districts of the interior have remained comparatively undisturbed, and a pure type seems to have survived, possibly from prehistoric times. This seems to be the case in many details of costume and domestic architecture: and comparative craniological research might lead to important conclusions. The results arrived at by Professor Levi in his measurements of recruits will, naturally, have to be taken into account; and no researcher can, of course, go any distance without mastering what has already been done by the Italian archæologists, and without the indispensable guidance of those on the spot. In this connection we cannot speak too highly of the courtesy and kindness of Professor Taramelli and Sig. Nissardi, the latter our companion for a fortnight, and of the hospitable welcome with which we were everywhere met. The views held by the latter¹ on the question of the purpose of the 'nuraghes' are most certainly correct, as we convinced ourselves by a careful examination of many of them in his company. That they are tombs, as Pinza maintained in vol. xi. of the 'Monumenti dei Lincei,' seemed to us to be impossible.

3. *Report of the Committee to Organise Anthropological Teaching and Research in the British Empire.*

4. *Report on Anthropometric Investigations among the Native Troops of the Egyptian Army.*—See Reports, p. 347.

5. *Nasal and Cephalic Indices in Different Parts of Egypt.* By Dr. C. S. MYERS.

6. *The Astronomy of the Torres Straits Islanders.* By W. H. R. RIVERS, M.A., M.D.

The islanders of the Torres Straits group together many stars in constellations, which often represent mythical persons. The constellations may in some cases be very large, including many of our own constellations: thus, the constellation

¹ See his paper in *Atti del Congresso Internazionale di Scienze Storiche*, Rome, 1903, vol. v., *Archeologia*, pp. 650-671.

Tagai represents the hero of this name standing in a canoe, holding a fishing-spear in one hand and a bunch of fruit in the other, and includes the Southern Cross, Scorpio, Sagittarius, Corvus, and stars of Lupus and Centaurus. Another constellation, The Shark, comprises the Great Bear, with the stars Arcturus and Gemma.

In Murray Island there was found to be private property in stars, the two stars of a constellation called The Brothers (Vega and Altair) belonging to two men who had inherited them from their ancestors.

7. *A Survival of Two-fold Origin.* By W. H. R. RIVERS, M.A., M.D.

There can be little doubt that the close connection found to exist in many races between a man and his maternal uncle is usually a survival of mother-right. There is, however, evidence that in at least one part of the world a connection which seems to be of exactly the same kind may be a survival of another feature of a previous social condition. In India there is often a very close relation between a man and his maternal uncle which becomes especially prominent during the wedding ceremonies; and it is probable that this has had its origin, at any rate in some cases, in the social regulation that the children of brother and sister should marry each other. Such a regulation involves the consequence that the maternal uncle of a man is at the same time his father-in-law, either actual or potential. It is probable that this marriage regulation was at one time widely prevalent throughout India, though at the present time it seems to be chiefly limited to the southern part of the peninsula; and there is some evidence from South India that the part played by the maternal uncle at the marriage of his nephew is due to the fact that he should by rights be occupying the position of father of the bride.

It would thus appear that customs linking together two relatives which seem to be very similar may yet have different origins, and may be survivals sometimes of a previous mode of descent, sometimes of an extinct marriage regulation.

8. *Demonstration of Photographs of Racial Types.*

By T. E. SMURTHWAITE.

The photographs exhibited show six distinct types:—

LONG-HEADED.

1. The Iberian: Facial contour oval, egg-shaped, or somewhat lozenge-shaped.
2. The Teutonic: Facial contour oblong or somewhat wedge-shaped.

BROAD-HEADED.

3. The Remian: Facial contour pear-shaped.
4. The Ligurian: Facial contour pentagonal, or five-pointed.
5. The Magian: Facial contour round or roundish.
6. The Celtic: Facial contour square or squarish.

The specimens show the above six types in England, Brittany, and Holland, with similar types from all parts of the world.

9. *Report on Anthropometric Investigation in the British Isles.*

See Reports, p. 349.

10. *Report on the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.*—See Reports, p. 383.

11. *A Rare Anomaly in Human Crania from Kwaiawata Island, New Guinea.* By W. L. H. DUCKWORTH, M.D., Sc.D., M.A.

In the large collection of human crania brought to this country by the Daniels Expedition are thirty-five specimens from the small island known as Kwaiawata, which is situated off the eastern extremity of New Guinea. Among these skulls three instances occurred of a singular anomaly, consisting in the presence of small but sharp spicular projections of bone springing from the margin of the nose. In one case they are present on both sides, in the others on one side only.

Such a condition is extremely uncommon, and it is curious to find it with such frequency in a small group of skulls like those from Kwaiawata. No other specimen from New Guinea in the Cambridge Anatomical Collection (whether among the skulls deposited by Major Daniels or in the University series) shows the condition. It occurs in a skull from New Britain, in two instances in crania from prehistoric cemeteries in Peru, and in one instance in a prehistoric British skull.

From these observations it seems to follow that the anomaly cannot be regarded as the peculiar product of local conditions at Kwaiawata; for, in fact, it is not absolutely peculiar to that island or even to that part of the world. Dissections made by me in the Anatomy School at Cambridge indicate that it is due to bony deposit formed in fibrous bands which in all cases exist in a corresponding situation; but we have no knowledge of the circumstances which determine the transformation of the usual ligamentous tissue into bone, with the production of the peculiar appearances to which reference has just been made.

12. *Observations made on an 'Eunuchoid' Subject in the Cambridge Anatomy School.* By W. L. H. DUCKWORTH, M.D., Sc.D., M.A.

Among the subjects dissected in the Anatomy School in the Lent Term last year was a large male of peculiar aspect. The most striking external features were an almost complete absence of hair (whether of the beard or on other parts of the body) and remarkably diminutive external genitalia. As already remarked, the subject was tall, and also fat, and curiously devoid of the normal (male) muscularity. It must be admitted that the age (returned as eighty-five years) must be taken into account herein.

Further research was principally directed to the microscopic appearances of the sex-glands, which were very small. They were found to be in a state of arrested development, and there can be little doubt but that the other appearances are related to this defect in evolution.

13. *The Races of South Africa.* By Dr. F. C. SHRUBSALL.

14. *Report on Archaeological and Ethnographical Researches in Crete.*
See Reports, p. 408.

SECTION I.—PHYSIOLOGY.

PRESIDENT OF THE SECTION—Professor FRANCIS GOTCH,
M.A., D.Sc., F.R.S.

THURSDAY, AUGUST 2.

The President delivered the following Address:—

‘THE investigators who are now working with such earnestness in all parts of the world for the advance of physiology have before them a definite and well-understood purpose, that purpose being to acquire an exact knowledge of the chemical and physical processes of animal life and of the self-acting machinery by which they are regulated for the general good of the organism.’¹

In this admirable and concise manner the late Sir John Burdon Sanderson described the aims and methods of physiology. The words were spoken in 1881, when the British Association last met in this historic city. At that time the subjects of Anatomy and Physiology formed a sub-section of the Section of Biology, and it was presided over by this distinguished man, whose recent death has deprived not only physiology but natural science of one of its most honoured leaders. His continuous work, extending over a period of fifty years, was remarkable from many points of view, but in none more than the extent of its scope. Sanitary science, hygiene, practical medicine, botany, pathology, and physiology have all been illuminated and extended by his researches. His claim for being included among the great names in English science does not rest merely upon his acknowledged eminence as an original and exact investigator, but also upon the influence which, for four decades, he exerted upon other workers in medical science, endowing their investigations with purpose and materially helping to give English physiology and pathology their proper scientific status. Many circumstances contributed to make this influence widely felt; among these were the peculiar charm of his manner, his striking and commanding personality, the genuine enthusiasm with which he followed the work of others, the devotion with which he advocated the use of experimental methods, his scientific achievements, and his extensive knowledge. All these qualities of mind and character marked him as one of those great masters who inspire the work and mould the thought of a generation. It is in tribute to his memory that, as one of his pupils and his successor in the Oxford Chair of Physiology, I utilise this occasion for recalling such fruitful features of his scientific conceptions as are expressed in the felicitous phrase which I have quoted.

Probably the most important of the many services which Burdon Sanderson rendered to English medical science was that of helping to direct physiological and pathological inquiry towards its proper goal. It will be admitted by all who knew him intimately, that among his most characteristic scientific qualifications were the insight with which he realised the essence of a physiological problem,

¹ Address to the Sub-section of Anatomy and Physiology, by J. Burdon Sanderson, *British Association Report*, York, 1881.

and the tenacity with which he kept this essential aspect in view. The faculty which enables the mind to review the varied aspects of complex phenomena and to determine which of these are mere incidents, or external trappings, and which constitute the core of the subject, is one which every scientific worker must possess in a higher or lower degree; it may, indeed, be confidently asserted that scientific training is successful only in so far as it develops a nice and just discrimination of this character. Many attain this capacity after several years of labour and effort; but in the case of rare and gifted individuals its possession comes so early as to seem almost an intuitive endowment. In 1849, during his student days at Edinburgh, Burdon Sanderson showed by the character of his earliest scientific work that he viewed the proper aim of physiological inquiry as essentially the study of processes. At the present time it may appear superfluous to dwell upon the importance of this standpoint, but fifty-seven years ago this aspect of the subject was rarely, in this country, a stimulating influence in physiological work, whilst, as regards pathology, the point of view taken by Sanderson was, even in 1860, probably unique.

The obvious fact that living processes occur in connection with certain definite structural forms transferred attention from the end to one of the means, and thus education and research in physiology and pathology were almost entirely confined to the elucidation of that structural framework in which the essential processes were now displayed and now concealed. Improved methods of microscopic technique revealed the complexity of this structure, and minute anatomy absorbed the interest of the few physiologists and pathologists who prosecuted researches in this country. Even when attention was directed to the living processes, it was with an unconscious anatomical bias, and detailed descriptions of structural framework were advanced as affording a sufficient scientific explanation of the character of the subtle processes which played within the structure. Yet upon the Continent the great physiologists of that time had long realised that physiological study must ascertain the characters of these processes, and that research conducted along experimental lines could alone advance scientific physiology as distinct from scientific anatomy. In 1852 Burdon Sanderson went from Edinburgh to Paris to study the methods used in physics and chemistry. Whilst there he came under the inspiring influence of one of these great Continental physiologists, Claude Bernard, and his views as to the proper end of physiological inquiry received from this master ample confirmation. The sentence which I have quoted from the York address sets forth with scientific precision his enlarged conception of living phenomena, for whilst it asserts that the characteristics of processes form the true aim of all physiological investigation, it defines the particular processes which should be investigated as chemical and physical, and it particularises two further aspects of these, the machinery for their co-ordination described as self-acting, that is automatic, and the *raison d'être* of their occurrence, which is said to be the welfare of the whole organism. All these various aspects are strikingly exemplified in the progress of physiology in this country and in the researches now being carried on both at home and abroad; their consideration may thus be not inappropriate in a general address such as it is my privilege to deliver to-day.

At the outset it is desirable to refer to certain wide issues which are involved in the statement that the business of the physiologist is 'to acquire an exact knowledge of the chemical and physical processes of animal life.' The limitation of physiology to ascertainable characters of a chemical and physical type does not commend itself to certain physiologists, physicists and chemists, who have revived under the term 'neo-vitalism' the vitalistic conceptions of older writers. They deny that physiological phenomena can ever be adequately described in terms of physics and chemistry, even if these terms are in the future greatly enlarged in consequence of scientific progress. It is undoubted that there are many aspects of living phenomena which in the existing state of our knowledge defy exact expression in accordance with chemical and physical conceptions; but the issues raised have a deeper significance than the mere assertion of present ignorance, for those who adopt 'neo-vitalism' are prepared to state not only that certain physiological phenomena are, from the chemical and physical point of view, inexplicable to-day,

but that from the nature of things they must for ever remain so. This attitude implies that it is a hopeless business for the physiologist to try by the use of more appropriate methods to remove existing discrepancies between living and non-living phenomena, and this is accentuated by the use of a peculiar nomenclature which, in attributing certain phenomena to vital directive forces, leaves them cloaked with a barren and, from the investigator's point of view, a forbidding qualification.

It is of course possible in describing phenomena to employ a new and special terminology, but since many aspects of the phenomena of living processes can be described in accordance with physical and chemical conceptions, the creation of a vitalistic nomenclature duplicates our terminology. A double terminology is always embarrassing, but it becomes obstructive when it is of such diversity that description in the one can never under any circumstances bear any scientific relation to that in the other. In this connection it is somewhat significant that the one kind, namely vitalistic, is abandoned as soon as the observed phenomena to which it referred have been found to be capable of expression in terms of the other. The reason for this abandonment raises questions of principle, which appear to me to render it impossible for a scientific physiologist to seriously employ vitalistic nomenclature in describing physiological phenomena. Science is not the mere catalogue of a number of observed phenomena; such a miscellaneous encyclopædia may constitute what many people would describe as knowledge; but science is more than this. It is the intellectual arrangement of recognised phenomena in a certain orderly array, and the recognition of any phenomenon is only the first step towards the achievement of this end. The potent element in science is an intellectual one essentially connected with mental grouping along one particular line, that which tends to satisfy our craving for causative explanation. Hence it involves the intellectual recognition of widespread characteristics, so general in their distribution that they are termed fundamental. The most fundamental of such characteristics are those which possess the widest intellectual sphere, and in natural science these are the broad conceptions of matter and motion which form the essential basis of both chemistry and physics. If this grouping is, in regard to any phenomenon, at present impracticable, then this subject matter cannot be justly regarded as forming a part of natural science, though it might be considered as natural knowledge, and in so far as this is the case in physiology it appears to me to be a confession of present scientific ignorance. If, however, it is boldly asserted that the nature of any phenomenon is such that it can never by any possibility be brought into accord with the broad conceptions which I have indicated, then I fail to understand how it can claim to bear any relation to natural science, since, *ex hypothesi*, it can never take its proper place in the causative chain which man forges as a limited but intelligible explanation of the world in which he lives. Only in so far as physiological phenomena are capable of this particular intellectual treatment and take part in this intellectual construction can we hope to obtain, however dimly, a knowledge of permanent backgrounds among the shifting scenes of the living stage, and thus, by gradually introducing order amidst seeming confusion, claim that gift of prevision which has long been enjoyed by other branches of natural science.

Neo-vitalism, like its parent vitalism, is fostered by the imperfect and prejudiced view which man is prone to take in regard to his own material existence. This existence is, for him, the most momentous of all problems, and it is therefore not surprising that he should assume that in physiology, pathology, and, to a lesser degree, in biology, events are dealt with of a peculiarly mystic character, since many of these events form the basis of his sensory experience and occur in a material which he regards with a special proprietary interest. He is reluctant to believe that those phenomena which constitute the material part of his existence can be intellectually regarded as processes of a physico-chemical type, differing only in complexity from those exhibited in the non-living world, and impelled by this reluctance he fabricates for them, out of his own conceit, a special and exclusive realm. The logical pressure of physical and chemical conceptions forbids the postulation, by either the public or the neo-vitalist, of such an incongruous

entity as a vital chemical element capable of blending with the familiar chemical elements recognised in the material world; yet the physiological processes of life are in popular estimation still held to be due to peculiar forces blending with those of the material world, but so essentially different that they can only be described as 'vital.' The neo-vitalistic school of scientists, without adopting this popular view in its entirety, retains the same term for such physiological characteristics of cell processes as, with our present limited knowledge and with our present inadequate methods of investigation, seem to be in disagreement with present chemical and physical conceptions. This disagreement is accentuated by the assumption of directive vital forces, and since these cannot be ranged alongside those of chemistry and physics, transcendental phenomena may be always expected to occur whose orderly array as part of natural science is not merely a futile but on *à priori* grounds an absolutely impossible task. In order to justify this description as representing the views of some neo-vitalists, I will quote a few sentences from the presidential address delivered in 1898 by Professor Japp in the Chemical Section of this Association. This address dealt with the formation of the optically active substances found in vegetable and animal tissues or their extracts. It asserts that 'the absolute origin of compounds of one-sided symmetry to be found in the living world is a mystery as profound as the origin of life itself.' In regard to this it may be remarked that the absolute origin of anything, living or non-living, is a mystery which science does not attempt to solve, relative not absolute causation being the object of scientific grouping, hence this assertion does not necessarily imply any fundamental distinction between the two classes of phenomena. But there is more than appears upon the surface, for the whole argument leads up to the sweeping statement that 'no fortuitous concurrence of atoms, even with all eternity for them to clash and combine in, could compass this feat of the formation of the first optically active organic compound.' It is thus inferred that because the manner of such formation cannot be accounted for in the present condition of scientific knowledge, its scientific causation is from the nature of things unknowable. However, although unknowable in the strictly scientific sense, the intellectual craving for causative explanation of some sort urges Professor Japp to say 'I see no escape from the conclusion that at the moment when life arose a directive force came into play.' There is here introduced a grandiose term for life which is viewed as involving directive forces; the term, however, adds nothing to our physiological knowledge, is not in itself explanatory, and not only offers no new method of physiological investigation but brands as useless all the methods derived from physics and chemistry, past, present, and future. In a recent work Professor Moore has attempted to set forth a conception which shall be vitalistic in essence, and yet not so completely out of touch with the principles of natural science.¹ He regards living cells as transformers of energy and thus leaves them absolutely dependent upon its receipt; the transformed mode which is achieved by the cells is, however, one which cannot be interpreted in terms of the familiar modes presented in the non-living world. He terms the transformed mode 'biotic energy,' and the distinction between this and 'vital directive force' appears to be its absolute dependence upon the other modes for its appearance. It thus does not run counter to the law of the conservation of energy, and warrants, in the opinion of some, the confident expectation that it will be found capable of precise scientific expression. I confess that I am unable to share this confidence. The introduction of the conception entails the same double terminology to which I have referred, and I feel convinced that the assumption, in the case of any given physiological phenomena, of biotic energy as a causative explanation, would be immediately abandoned if the phenomena were subsequently found to be explicable on physical and chemical conceptions. Biotic energy appears to me as only an intellectual compromise, an abortive attempt to clothe the naked form of vitalism in a decent scientific dress; but, although partially clothed, it offers, like neo-vitalism, no new method for physiological investigation, and must, in consequence,

¹ See article by B. Moore in *Recent Advances in Physiology and Biochemistry*, Edited by L. Hill, F.R.S. (London: Arnold, 1906.)

remain barren, never contributing towards physiological achievement. To what extent its adoption may be an intellectual solace is a question which does not fall within the scope of physiology. Certain physiological phenomena are especially brought forward as necessitating the assumption of vitalistic or biotic conceptions; among these are the phenomena of nervous activities, the formation and activities of enzymes, and the passage of substances through living membranes. The question of the nervous activities will be dealt with later; but as regards the diffusion of gases or substances in solution through cellular membranes a few general considerations may be advanced now.¹ The passage of substances into and through non-living membranes is modified in regard to both the velocity and the selective character of the passage by a large number of factors, among which are nature of substance, pressure, osmotic index, temperature, and the structural, electrolytic, and chemical characters of the membrane. Tissue membranes, whether animal or vegetable, possess a complicated particulate structure, and it is obvious that experiments must be carried out extensively on dead tissue membranes in order to determine how far the general particulate arrangement may modify the rate and character of the passage. In this respect our present information is not sufficiently extensive to warrant any definite general statement, and such experimental evidence as exists opens up difficult problems in molecular physics which still await solution; moreover, the presence of electrolytes, by assisting adsorption, appears to modify the apparent rate and character of the total passage, and further experiments are necessary on this point. But in the living membrane, especially when it is composed of cellular units, the whole question is additionally complicated by the great probability that the cells are the seat of chemical processes the nature of which is imperfectly known; such processes constitute the metabolism of the cells. It would, therefore, be somewhat surprising if the phenomena of the passage of substances through such cellular membranes were in strict accord with the passage of similar substances through non-living membranes which have not the same particulate framework and are not the possible seat of similar chemical processes. The statement, therefore, that any discrepancy between the two classes of phenomena necessitates the assumption of a peculiar vital directive force disregards the circumstance that between the conditions in the one case and those in the other lies a large and little explored field; moreover, such a statement implies, without any warrant, that any physico-chemical explanation must necessarily be insufficient in the case of the living membrane, although it is realised that there may be active chemical processes of whose operations we have at present little exact knowledge.

What possible justification is there, therefore, for branding as hopeless all further physical and chemical investigation of certain aspects of the phenomena by attributing these to vital directive forces? The gaps and imperfections of the palæontological record were triumphantly vaunted by the opponents of evolution; and now that the work of successive years has convincingly contributed towards the filling up of these gaps not only has this objection collapsed, but the hypothesis of special creations which it supported has been involved in its fall. There are indications that the discrepancies in diffusion phenomena through widely different structures may be knit by the results of experiment on intermediate modifications. It may be many years before these are completed, but the introduction of vitalism or biotic energy as a fictitious causative explanation is so opposed to the spirit and the progress of science that we may safely predict the complete abandonment of this position at a comparatively early date.

I venture now to define my own position in regard to this matter. I assert that, although the complexity of living tissues makes our present knowledge

¹ The conception of Ostwald as to the action of catalytic substances is extremely suggestive in connexion with the activities of enzymes, both intracellular and extracellular. It is possible that the changes brought about by enzymes may, with the growth of our knowledge, in physical chemistry, be shown to be of the same order as those which slowly occur in the absence of enzymes, and that the enzyme itself by facilitating adsorption phenomena may merely act by accelerating the velocity of the special change. See Leathes, *Problems in Animal Metabolism* (London: Murray, 1906).

extremely limited, it is essentially unscientific to say that any physiological phenomenon is caused by vital force or is an argument in favour of 'vitalism,' and that, if this phraseology is offered as a sufficient description of the phenomenon, its further scientific study is prejudiced because the only terminology which admits of scientific exactitude is excluded. I assert, further, that if the term 'vitalism' connotes no more in physiology than the term 'living,' its employment does not in any way enlarge our intellectual view of the subject-matter of physiology, and can only be considered either as meaningless tautology or as an expression of faith; but if the term has some additional, occult, and mystic significance, then its employment is detrimental to the progress of physiology, exerting as obstructive an influence upon the growth of our science as the conception of special creation exerted upon the progress of biology.

Vitalism is not the only 'ism' which, perhaps unwittingly, obstructs physiological progress; it is, however, far more worthy of respect than others which I do not propose to particularise, for it is a twig of that lusty tree which, in philosophy, still claims the largest share of men's belief. The vitalist, leaving the more solid ground of physics and chemistry, enters the realm of metaphysics and there attaches himself to that distinguished circle of idealists whose pedigree extends back to Plato. If, as may be asserted with great confidence, idealism in philosophy will endure as long as thought exists, then it might be expected that vitalism in physiology will never entirely cease. The history of physiology, however, reveals the fluctuating extent of its influence. Potent a century or more ago, vitalism nearly disappeared between 1850 and 1870 under the pressure of the application of physical and chemical methods to physiology; it revived again towards the century's close, the ripple of a wide-spreading wave of idealistic philosophy. Materialism and idealism have been described by Huxley as appearing in the history of philosophy like 'the shades of Scandinavian heroes eternally slaying one another and eternally coming to life again.' As a physiologist, I do not venture to touch however lightly upon this metaphysical duel, since I frankly admit my own incapacity to do so and the particular applicability to my own powers of the words of Gibbon that 'it is much easier to ascertain the appetites of a quadruped than the speculations of a philosopher.' It is therefore without any intention of casting any suspicion of doubt upon the confidence felt as to the persistence of idealism in philosophy, that I suggest that neo-vitalism in physiology bears upon its surface the signs of its own decay. One such sign is the circumstance that even its most ardent exponents refuse to follow the lead of this *ignis fatuus*, but assiduously investigate living processes by the most improved chemical and physical methods; another is that when any so-called vitalistic aspect of some physiological phenomenon is rendered explicable on physical and chemical lines, the vitalist abandons in this instance his peculiar standpoint. Neo-vitalism has of late thus lost its corrosive character; it now spreads as a thin but tenacious film over physiological conceptions and is in this way mildly obstructive, but its obstructive viscosity is continually yielding to the accumulating mass of the more precise knowledge which it endeavours to obscure. Research along physical and chemical lines into physiological processes is its uncompromising opponent, so that there is every reason for believing with Huxley that the weight and increasing number of those who refuse to be the prey of verbal mystifications have begun to tell.

The recent history of physiological progress shows that investigations confined to the study of physical and chemical processes have been the one fruitful source of physiological knowledge. It would be impossible to give even a brief survey of the chief results which have, during the last twenty years, been thus obtained. Out of the enormous wealth of material I select one of great importance and promise. It is that of the constitution of the nitrogenous compound familiarly known as proteid, which from its close association with protoplasm, the physical basis of life, has a fundamental significance and has therefore attracted the attention of many competent investigators. Important researches have been made on this subject by physiological chemists, notably Hofmeister and Kossel, and at the present time the subject is also being studied by one of the ablest organic chemists of the day,

Emil Fischer, whose previous work on carbohydrates is so illuminating.¹ In the splendid chemical laboratory at Berlin, with its unparalleled equipment, a succession of researches have been carried out dealing not only with the constitution of the simpler proteid derivatives but also with the important and difficult problem of the synthetic grouping of these derivatives into more complex compounds. The success which has so far attended these investigations is so pronounced as to encourage the hope that the future may reveal the chemical constitution of proteid itself and thus bring us perceptibly nearer to its possible synthetic formation. We congratulate ourselves that this problem has at last attracted the earnest attention of organic chemists.

I now invite your attention to those further aspects indicated in the opening sentence of this address, which imply the presence of automatic mechanisms by which the various processes of the body organs are regulated and co-ordinated for the welfare of the whole organism.

Many such automatic mechanisms are now known. Some of these are of an obvious chemical type, the mechanism being the production in minute quantity of chemical substances which are conveyed to remote organs by the circulating blood. In this way adrenalin, a substance elaborated by the medullary portion of the suprarenal organs, augments the activities of the muscles, particularly those of the arterioles. From his recent researches, Langley² is disposed to believe that many chemical compounds which augment or diminish the activity of muscles and glands do not act by altering the differentiated tissue but play upon a hypothetical receptive substance which lies at the junction of the tissue with its entering nerves. This middleman, so situated as to lie in the interstices of the neuro-muscular junction, bears a relation to the muscle or gland-cell somewhat analogous to that which the fulminating cap bears to the cartridge, and it is quite conceivable that it is maintained in an appropriate condition of instability or explosiveness by the direct action of chemical substances conveyed to it in minute amounts by the blood.

It is remarkable how many of these strictly chemical automatic mechanisms have been discovered in the last few years, thus substantiating the views of Brown-Séquard. The automatic character of the mechanism which determines the secretion of the pancreatic fluid was revealed by the experiments of Bayliss and Starling, which showed that definite chemical compounds are formed in the lining cells of the small intestine, and that treatment with weak acid, such as occurs in the acid chyme, liberates a substance which, absorbed into the blood, has the special function of stimulating the pancreatic cells.³ A similar automatic mechanism has been found by Edkins to exist in the stomach, for although the flow of gastric juice is initiated by nervous channels, the subsequent peptic secretion is largely augmented through the presence in the blood of chemical substances elaborated and absorbed in the pyloric portion of the stomach wall.⁴ Marshall and Jolly have recently shown that substances elaborated in the maternal ovaries, and particularly in the corpus luteum,⁵ determine, when introduced into the circulating blood, the changes necessary for the proper attachment of the embryo to the uterine wall and thus the further development of the embryo during the first stages of pregnancy. The researches of Starling and Miss Lane-Clayton indicate that chemical substances formed during pregnancy in the tissues of the foetus will, if introduced into the maternal blood, directly evoke the appropriate activities of the remote mammary glands.⁶

¹ E. Fischer, *Berichte Deutsch. Gesellschaft*, xxxviii. 1905. (See also 'La synthèse des matières protéiques,' par L. C. Maillard. *Revue Générale des Sciences*, Févr. 1906. Paris.)

² J. N. Langley, *Journ. of Physiol.*, xxxiii. 1905, p. 374, and Croonian Lecture, Roy. Soc., 1906.

³ Bayliss and Starling, *Journ. of Physiol.*, xxviii. 1902, p. 325.

⁴ Edkins, 'On the Chemical Mechanism of Gastric Secretion,' *Proc. Roy. Soc., B*, lxxvi. 1905, p. 376.

⁵ Marshall and Jolly, *Phil. Trans. Roy. Soc. London, B*, 1905, p. 198.

⁶ Starling and Lane-Clayton, *Proc. Roy. Soc., B*, lxxvii., 1906, p. 506.

These are only a few instances of a class of mechanisms, strictly chemical in character, by which the activities of remote and dissimilar organs are automatically co-ordinated; a further class of such mechanisms, although involving a chemical substance conveyed by the blood, carries out the actual regulation by means of the central nervous system. An example of this class is afforded by the researches of Haldane and Priestley upon the carbonic-acid gas in the pulmonary air. These show that the alveolar pressure of carbonic acid in the lung spaces remains constant even when the atmospheric pressure is considerably altered in amount. The constancy is due to the circumstance that the respiratory nerve centres are exquisitely sensitive to a rise in this carbonic-acid pressure. Any such rise slightly augments the carbonic-acid tension of the pulmonary blood, which, on being conveyed to the nerve centres, arouses their greater activity, and the increased efficiency of the respiratory ventilation, thus produced, rapidly reduces the amount of the very agent which is its exciting cause.¹ The researches of Hill and Greenwood, with air pressures up to seven atmospheres, bear out the conclusion that by this automatic mechanism the air in the lung alveoli has a practically constant pressure of carbonic acid in any given individual.²

The introduction, in this example, of the respiratory centres and nerves raises the question whether the nervous system, which is in a very special sense the channel for the regulation and co-ordination of the various activities of the body, may not itself be conceived to be a supreme example of an automatic physico-chemical mechanism, the transference from one part to another taking place, not through the flow of blood containing chemical substances, but through a more subtle physico-chemical flow along the highly differentiated nervous strands of which this system consists. The nervous system is not popularly regarded in this light; on the contrary it is considered to be the special seat of vital directive forces, and it is held, even by some scientific men, that the nervous energy which it manifests is so transcendental in its essence that it can never be brought into line with those modes of energy prevailing in chemistry and physics. There is, moreover, a widespread belief, founded upon conscious volitional power, that nervous energy can be spontaneously created, and that even if its manifestations are bound up with the integrity of certain definite nervous structures, these structures only form the material residence of genii, temporarily in possession endowed with the powers of hypothetical homunculi at whose bidding the manifestations either take place or cease.³

The complexity of nervous structure and the apparently uncertain character of nervous activities furnished the older writers with plausible reasons for assuming the existence of animal spirits, but the extensive researches of half a century progressively suggest that nervous phenomena may be regarded as the sum of particular physico-chemical processes localised in an intricate differentiated structure, the threads of which are being unravelled by neurological technique. This chapter of physiology still bristles with difficult problems and obscure points, yet the unmistakable trend of the immense advances which have been made in recent years is towards the assumption that nervous processes do not in their essence differ from processes occurring elsewhere in both the living and non-living worlds.

As regards structure it is generally assumed by neurologists that the whole system is a fabric of interwoven elements termed neurons, each with a nucleated nerve-cell and offshoots, one of which may be extended as a nerve fibre, whilst no nerve fibre exists which is not the offshoot of one such cell. This neuron theory

¹ Haldane and Priestley, 'The Regulation of Lung Ventilation.' *Journ. of Physiol.*, xxxii. 1905.

² Hill and Greenwood, 'The Influence of Increased Barometric Pressure on Man.' *Proceedings Roy. Soc.*, vol. lxxvii. B, 1906, p. 442.

³ Lodge, *Life and Matter* (London: Williams and Norgate, 1906.) 'Matter is the vehicle of mind, but it is dominated and transcended by it' (p. 123). 'Contemplate a brain-cell, whence originates a certain nerve-process whereby energy is liberated with some resultant effect' (p. 168). 'It is intelligence which directs; it is physical energy which is directed and controlled and produces the result in time and space' (p. 169).

is based upon developmental history and upon the suggestive fact that each nerve cell forms an independent trophic centre for its own distributed processes. It is undoubted that, like the atomic theory in chemistry, the neuron theory has proved of enormous service, enabling neurologists to disentangle the woven strands of nerve-cell processes even in such an intricate woof as that of the central nervous mass. There are, however, difficulties associated with its full acceptance in physiology, as indeed there are said to be in connection with the full acceptance of the atomic theory in chemistry; but dismissing these for the moment, I pass on to consider the presumable character of such a conception of nervous activities as would be demanded on the supposition that the nervous system is, as regards all essentials, an automatic physico-chemical mechanism.

In the nerve fibres, which are undoubtedly the offshoots of nerve cells, the only demonstrable changes during the actual passage of nervous impulses are of an electrical type. These resemble the effects which would occur if there were redistributions of such electrolytes as are known to exist within and around the differentiated fibrillated core or axon of each nerve fibre. All the better-known aspects of nerve-fibre activities are in accordance with such an electrolytic conception. The exquisite sensibility of nerve to physical and chemical changes of a sudden character would be associated with the fluctuating and variable character of electrolytic distribution, this instability being characteristic of particular electrolytes in colloidal solutions; hence physical and chemical alterations primarily affecting the nerve envelope will, by modifying the electrolytic distribution, produce physico-chemical change in the internal axon itself. Such changes, when once produced at any point in the differentiated fibrillar continuum of the nerve fibre, must in accordance with the conception first propounded by Hermann be propagated or transmitted along this continuum. The redistribution of electrolytes at the seat of the external impression being itself a source of electromotive effects, electrical currents demonstrably flow from this point into the contiguous parts of the fibrillar continuum. Such flow of current must reproduce in this neighbouring continuum that electrolytic redistribution which is the fundamental aspect of nerve-fibre activity. Thus, by this comparatively simple automatic mechanism, the physico-chemical electrolytic change is successively assumed by the various portions which compose the length of the differentiated axon, and the new or active phase is propagated along a nerve fibre as infallibly as a flame speeds along a fuse when one end is ignited; in this way the conception explains how a so-called nervous impulse is brought into being. Further, the brief duration of the activity of the nerve, its rapid development and slower decline, and the circumstance that a second external change cannot arouse a second activity if it occurs very shortly after an effective predecessor, all have their counterpart on the electrolytic side, and we have convincing evidence that the electrolytic redistribution during activity cannot be again produced until the electrolytic condition has more or less returned to its original resting poise: the real peculiarity of the living tissue is its persistent tendency to re-establish the electrolytic concentration of this resting poise.¹ Finally experiments show more and more convincingly that the capacity of the nerve to respond to external changes, as well as the magnitude and duration of the aroused activities, are particularly susceptible to modification by all those agents which are most potent in affecting electrolytic aggregates, such as temperature, electrolysis, and impregnation with various electrolytes.

These electrical indications of nerve-fibre activities are fundamentally the same whether the fibres occur in peripheral nerve trunks or in the bundles which course through the central masses; and thus, if the whole system consisted of nothing but the united strands of differentiated nerve fibres, nervous phenomena would be merely the expression of the development, along appropriately distributed tracts, of similar electrolytic changes primarily started by some external physical or chemical alteration. But additional complications are introduced by the existence of nerve-fibre endings and by the interposition

¹ Gotch and Burch, *Journ. of Physiol.*, vol. xxiv. 1899, p. 410.

of the nerve cells. According to the neuron theory the fibres of different nerve cells end more or less blindly, and, at any rate in vertebrates, do not demonstrably unite at their termini within the central mass; hence gaps exist at the junction unbridged by the differentiated structural continuum. But since the nervous impulse can pass from one set to the other, a physiological continuum undoubtedly exists; it is necessary, therefore, to assume either that the electrolytic change in one neuron can by mere contiguity in space arouse a similar change in a neighbouring neuron process, or that a differentiated connection actually exists, but of such structural delicacy that it cannot be microscopically demonstrated. Recently several physiologists have stated their belief in such continuity; one of these, E. Pflüger, bases his view upon the admitted intracellular nature of peripheral nerve endings in muscles, glands, epithelial cells, and electrical organs. Arguing from analogy, he infers that the central nerve endings of one neuron probably pierce and enter the cell processes of another neuron.¹ Such a connection can be actually seen, as a pericellular plexus, in the ganglia of crustacea, and has been occasionally described as observed in higher animals.¹ Whether the central termini of neuron processes are in reality joined by extremely fine fibrillar filaments or whether they end blindly in mere juxtaposition, it is undoubted that the functional synopsis presents peculiar features. The chief peculiarities of synaptic activities as distinct from the activities of the nerve fibres are the following: Marked retardation in the maximum rate of propagation; irreciprocity of conduction, which is favoured in the natural or homodromous direction, whilst in the unnatural or heterodromous direction it is obstructed or completely blocked; susceptibility to fatigue; special susceptibility to stimulation and impairment by definite chemical substances, by strychnine, absinth, anæsthetics, &c.; the presence of a resistance which diminishes rapidly when subjected to the assault of a series of entering or centripetal nervous impulses even when each member of the series is alone quite powerless to force a passage. All these peculiarities are more or less demonstrable in all nerve endings, peripheral as well as central, and are presumably, therefore, related to the character of the propagation which occurs in the finely-divided non-medullated twigs or 'arborisations' into which the nerve fibres break up in such endings, and possibly to some further 'receptive' substance lying beyond the endings. The retarded propagation, showing itself by an apparent delay, occurs in the motor nerve endings of muscles and in the multitudinous nerve endings of electrical organs, as well as in the central nervous system. Gärten's researches on non-medullated nerves suggest that it may be connected with such slowed development of the electrolytic redistribution and of its accompanying electromotive alterations as is demonstrable in these structures.² Irreciprocity of conduction occurs where nerve endings are continued into muscle substance, since the activity process passes from nerve to muscle, but not the reverse way. In 1896 Engelmann succeeded by means of a double muscle-bath in so modifying one end of a muscle fibre that the wave of contraction, whilst it travelled freely along the muscle fibre from the unmodified to the modified portion, would not do so the reverse way.³ The particular modification which produced this abnormal result is an interesting one; it is the development of an abnormally sluggish type of mobility, the whole activity of the modified region being greatly prolonged by means of veratria. This suggests that difference in the duration of the active process on the two sides of a central nervous synopsis would, if present, be one factor in producing the well-known central irreciprocity. The susceptibility to fatigue may be associated with this augmented difficulty of propagation, and it undoubtedly occurs to a marked extent in muscular nerve endings; for, according to the investigations of Joteyko, it may be more pronounced in this peripheral ending than it is even in the spinal cord.⁴ Even

¹ E. Pflüger, 'Ueber den elementaren Bau des Nervensystems,' *Archiv f. die Ges. Physiol.* cxii., 1906.

² Gärten, *Beiträge zur Physiologie der marklosen Nerven*, Jena, 1903.

³ Engelmann, 'Versuche über irreciproke Reizleitung in Muskelfasern,' *Archiv f. die Ges. Physiol.*, lxii. 1896, p. 400.

⁴ Joteyko, *Travaux de l'Institut Solway*, Bruxelles, iii. 2, 1900.

the so-called summation phenomena—that is, the ease with which a succession of centripetal impulses can force a passage as opposed to the difficulty with which a single such impulse does so—is not peculiar to the central mass, but is observed more or less in peripheral nerve endings; for instance, those of electrical organs. Finally, the results obtained by Wedenski suggest that anæsthetics have a particular affinity for nerve endings, including the peripheral ones in the muscles; and although the causation is at present imperfectly known, it does not seem improbable that they may act upon some such specific substance as that which is conceived of by Langley under the term ‘receptive.’¹

All the phenomena hitherto described are thus not necessarily aspects of the activity of that particular mass which constitutes the body of the nerve cell, but of nerve endings with their fine arborisations. As regards direct electrical evidence of electrolytic changes in these finer branches, it so happens that Nature has provided some nerve endings on such a magnificent scale that this evidence is readily obtained. In the electrical organs of fishes the essential structure consists of a pile of numerous discs each invaded by nerve endings, and the electric shock of the fish is the sum of all the electrical changes in this pile when an efferent nervous impulse reaches each of its component discs. Its potency is due to the number of these components, but in each single component it is of the same order as the electromotive change in a nerve, and its character is such as might be produced by electrolytic redistribution occurring simultaneously in the immense number of nerve endings which are present in each disc of the electrical organ. Although displaying the peculiarities of apparent delay, &c., just referred to, the general character of the shock of the organ is such as to warrant the belief that electrolytic conceptions of nerve-fibre activity can be extended to the activities of nerve endings.

There remains that special part of the whole neuron which is the effective source both of its development and of its maintenance, the nerve cell. Continuity with a nerve cell is essential for the integrity of both the structure and the function of a nerve fibre, but it is undoubted that, in its turn, the nerve cell is also dependent upon the existence of its processes in an unimpaired state. Thus the cell suffers a change which comes on slowly but with great certainty if any part of the neuron has been mutilated, or if the cell has been shorn of some of its offshoots. That it forms a special part of the conducting path is indicated by the occurrence of intracellular and nuclear alterations when a prolonged series of impulses travel towards it, and a further more remarkable point is that it also appears to change if the entering nervous impulses with their electrolytic concomitants are no longer able to reach it. This suggests that nerve cells, far from being spontaneous actors, are in a very real sense dependents; they form only one possible conducting portion of the whole differentiated tract, and atrophy when this tract is broken or is from any circumstance not utilised. That the cell is primarily trophic and only incidentally a conductor is suggested by Bethe's experiments upon crustacea. Owing to pericellular connections the actual nerve cell may be removed in these animals without severing the whole conducting tract, for a portion lies around but outside the cell; and since, even after such removal, the usual reflex movements of the supplied antennæ are resumed, the cell cannot in this instance be regarded as essential for the discharge of the motor impulses which evoke the antennæ movements.²

In higher animals such removal of the cell body has been imperfectly carried out by Steinach in the dorsal spinal ganglia but in the central mass it is impossible to perform a crucial experiment of this kind so as to determine whether or no the substance of nerve cells can create nervous impulses. There are two particular features of reflex movements which may be cited as indicating that a motor nerve cell has at its call a store of nervous energy which it can spontaneously discharge. The first of these is the well-known fact that the character

¹ Wedenski, ‘Erregung, Hemmung und Narkose,’ *Archiv f. die Ges. Physiol.* c., 1903.

² Bethe, *Allgemeine Anat. u. Physiol. des Nervensystems*, 1903, p. 99.

of reflex movements is such as to indicate the rhythmical discharge of groups of centrifugal nerve impulses whose periodicity bears no relation to that of the centripetal ones. But it must be remembered that even in nerve fibres it is possible for a succession of stimuli to evoke a different succession of electrolytic changes and of nerve impulses, provided that some of the successive stimuli fall within the period of inexcitability which occurs during the establishment of each new electrolytic poise.¹ We have, therefore, only to assume, as is very probable, that in the central portion of the nervous path this poise is prolonged in its development, and numbers of centripetal impulses must necessarily fail; hence the emergent ones will have a special periodicity indicative of the duration of the swing of the electrolytic rearrangement which occurs when the synapses *plus* the cells are traversed by the entering impulse.

The second feature which more particularly suggests spontaneous cellular activity is the well-known fact that reflex centrifugal discharges may continue after the obvious centripetal ones have ceased. This is pre-eminently the case when the central mass is rendered extremely unstable by certain chemical compounds, such as strychnine, &c. There are, however, suggestive indications in connection with such persistent discharges. The more completely all the centripetal paths are blocked by severance and other means, the less perceptible is such persistent discharge, and since nervous impulses are continually streaming into the central mass from all parts, even from those in apparent repose, it would seem that could we completely isolate nerve cells, their discharge would probably altogether cease. In this connection a suggestive experiment was carried out some years ago upon the spinal cord of the mammal.² A portion was isolated *in situ* by two cross-sections, and a part of this isolated cord was split longitudinally into a ventral half containing the motor or centrifugal nerve cells and a dorsal half containing the breaking up of the centripetal nerves; each half was then examined for those electrolytic changes which indicate the presence of nervous impulses. It was found that, even in the strychnised animal, no electrical effects could be detected in the ventral half of the cord or its issuing roots, although such effects were marked in the whole cord, and occurred in the dorsal half which contained the centripetal nerve fibres.

This experiment indicates that even in the hyper-excitable condition produced by strychnine the spinal motor nerve cells did not discharge centrifugal impulses when cut off from their centripetal connections. It is corroborated by the results obtained by Baglioni in the frog and small mammal,³ and, taken in connection with those previously mentioned, it affords considerable foundation for asserting that the chief *rôle* of the nerve cell is trophic, and that, as regards issuing nerve impulses, it only forms a modified part of the conducting path. The more we investigate the physiology of the nervous system, the stronger becomes our belief that for centrifugal discharges to occur centripetal impulses must be primarily started either in the peripheral sensory surfaces by changes of a physical or chemical type occurring in the external world, or at some point in the nerve continuum by local chemical or physical changes within the body, especially those due to the chemical condition of the blood. Having been thus started they course along definite structural paths, and the only direct indications of this passage consist of such phenomena as would be produced by the redistribution of concentrated groups of electrolytes—a purely physico-chemical process.

This conception places the propagation of the nervous excitatory state as the sole determining factor of nerve activities, central or peripheral. It derives additional support from the circumstance that it is in harmony with that aspect of these activities which is comprised under the term, inhibition. Any effective regulating system must be able to bring into play both incentive and

¹ Gotch and Burch, *Journ. of Physiol.*, vol. xxiv. 1899, p. 410; Boycott, *Journ. of Physiol.*, vol. xxiv. 1899, p. 144; Buchanan, *Journ. of Physiol.*, vol. xxvii. 1901, p. 98, &c.

² Gotch and Horsley, *Phil. Trans.*, vol. clxxxii. pp. 267-526. (London, 1891.)

³ Baglioni, *Archiv f. die Ges. Physiol.*, 1900, Supplement, pp. 198-242. (Leipzig.)

restraint—the whip and the reins. The possession by the central nervous mechanism of inhibitory powers is remarkable both for its extent and its delicacy. It appears more and more probable that this is achieved by the propagation of nervous impulses of the ordinary type. Thus, recent researches by Sherrington show that the propagated impulses from a given central mass may, although normally inhibitory to the centrifugal discharge of another mass, become directly incentive if the second controlling centre has its excitability abnormally augmented by strychnine, tetanus toxin, &c.¹ As regards their fundamental characters it thus appears that both augmenting and inhibiting impulses belong to the same category. Moreover, such theories of central inhibition as embrace all the phenomena involve as their essential basis the cutting-off of the potent centripetal supply to the inhibited centre. In the interference theory this cutting-off is assumed to be caused by the arrival of other nerve impulses which, breaking into the path of normal centripetal flow, obstruct and run counter to this potent stream. In the ingenious drainage theory, propounded by McDougall, the cutting-off is an indirect one, it being assumed that the new stream enters other side-channels, and thereby opens up a short circuit through which the potent ones drain away without reaching the centrifugal centre. Even Langley's conception of receptive substances played upon by impulses must be associated with a check in the efficiency of the continuous centripetal supply.

From the foregoing it appears that the physiologist has definite grounds for believing that, as far as present knowledge goes, both the production and cessation of central nervous discharges are the expression of propagated changes, and that these changes reveal themselves as physico-chemical alterations of an electrolytic character. The nervous process, which rightly seems to us so recondite, does not, in the light of this conception, owe its physiological mystery to a new form of energy, but to the circumstance that a mode of energy displayed in the non-living world occurs in colloidal electrolytic structures of great chemical complexity. There is a natural prejudice against the adoption of this view, but such prejudice should surely be mitigated by the consideration that this full admission of physiology into the realm of natural science, by forcing a more comprehensive recognition of the harmony of Nature, is invested with intellectual grandeur.

With such questions as the essential meaning of consciousness and the interpretation of the various aspects of mind revealed by introspective methods, the physiologist, as such, has no direct concern. For his purpose states of consciousness are regarded merely as signs that certain nervous structures are in a state of physiological activity; and he thus limits the scope of physiology to the objective world. This limitation of physiology does not prohibit a treatment of the subjective world along lines calculated to display that intellectual causative array which characterises science; it merely indicates that this particular application of scientific method is not physiology, but that something else, still more profound, which is now termed psycho-physics.

But if objective phenomena form the subject-matter of the physiologist, then 'the legitimate materialism of science' must constitute his working hypothesis; and his 'well-defined purpose' must be to adapt and apply the methods of physics and chemistry for the analysis of such phenomena as he can detect in all physiological tissues, including the nervous system. The trend of such a strictly physiological analysis is towards a conception in which the highest animal appears as an automaton composed of differentiated structures exquisitely sensitive to the play of physical and chemical surroundings.² The various parts of the animal body are linked by circulating fluids and by one special structure, the nervous system; in this linking of parts the physiologist detects the working of automatic chemical mechanisms of great delicacy which, once developed, are retained and perfected in proportion as they efficiently regulate the various bodily activities and co-ordinate

¹ Sherrington, *Proc. Roy. Soc.*, vol. lxxvi. B, pp. 269-297. (London, 1905.)

² See *Huxley* 'On the Hypothesis that Animals are Automata,' Evening Address; *Brit. Assoc.*, Belfast, 1874. Republished in *Collected Essays*, vol. i. (Macmillan, 1904.)

them for the welfare of the whole organism. The plastic nature of nervous tissue renders it, in accordance with the principles of natural selection, particularly favourable for progressive change in this direction, and thus developments may occur which reach their highest physiological expression in the brain of man.

In conclusion attention may be drawn to the peculiar instability of living processes and structures. The living units show that significant mutability which the physiologist describes as metabolism. This mutability appears to be encouraged or discouraged by the extent to which it fulfils a purpose, and this purpose in a living organism is the dominating law of its own development. The fulfilment of this purpose by means of physical and chemical change is such a general characteristic of living processes that a physiologist may with some confidence suggest that this fulfilment is the distinctive mark of a living thing.

The following Paper and Report were read :—

1. *Granular Changes in Nerve Fibres.*
By Professor J. S. MACDONALD, B.A.

2. *Report on the Metabolic Balance Sheet of the Individual Tissues.*
See Reports, p. 426.

FRIDAY, AUGUST 3.

The following Papers and Reports were read :—

1. *The Nitrification of Sewage in Shallow Filters with Fine Particles.*
By Dr. GEORGE REID.

The author has always advocated fine-grain sewage filters, used as 'percolating' filters, not as 'contact' beds; but until recently he was not aware that the reduction in the size of the filter particles allowed of much shallower and, therefore, less costly filters being constructed.

At present the Local Government Board pay no regard to size of particles or depth of filter so long as a minimum depth of four feet is provided, the sole governing principle being cubic capacity in relation to sewage flow, irrespective even of the strength of the sewage. It follows, therefore, that for a given volume of sewage the area of an 8-foot filter need only be half that of one four feet deep, the rate of delivery per superficial yard in the case of the former being twice that of the latter.

Seeing that nitrification is dependent upon the healthy activity of aërobic organisms, theoretically it would seem that, the larger the number of these organisms, the greater the amount of work they can accomplish. If this is so, the aim surely should be to provide, within a given space, as large a surface for bacterial growth as possible, by reducing the filter particles to the smallest size which is found to be compatible with free aëration and practical working conditions.

In practice, the author has found that the best results are obtained from $\frac{1}{8}$ -inch filter particles, although from 1 to 3 or 4 inches is the range usually adopted for percolating filters.

The author had recently an exceptional opportunity of following up the process more in detail at disposal works which had been in constant operation for nearly four years, yielding invariably high-class effluents. Accordingly, the

directed his attention specially to the gradational changes effected at different depths by analysing samples collected by a series of trays introduced into the body of the filter at 1-foot intervals, the trays being placed obliquely from above downwards, so that no tray had another in the vertical line above it.

The plant consisted of (a) a straining-chamber of the usual type; (b) three detritus tanks of a total capacity of one-eighth the dry-weather flow; (c) a septic tank which, with the detritus tank, gave a period of quiescence of twenty-four hours; and (d) a quarter-acre percolating filter, 4 feet 6 inches deep, formed of $\frac{1}{2}$ -inch particles of a hard, non-friable character, the septic tank effluent being applied to the filter at the rate of 200 gallons per superficial yard, by means of a power-driven apparatus which distributed the sewage with perfect uniformity at five-minute intervals throughout the twenty-four hours.

The following are the more important results of a series of analyses of samples collected over a period of six months, the filter having been in constant use for three years previously.

The suspended solids in the tank effluent, amounting to 7.6 parts per 100,000, of which 50 per cent. was mineral matter, were practically all retained in the superficial layers of the filter, where the organic portion was evidently liquefied—probably by aërobic organisms. Within the first foot the organic matter was nearly completely oxidised, the free ammonia in parts per 100,000 being reduced from 1.71 to 0.03, the albuminoid ammonia from 0.34 to 0.05, and the oxygen absorbed from 2.18 to 0.32, a nitric nitrogen figure of 2.07 being recorded. It will thus be seen that a very high-class effluent resulted from filtration through one foot only, and that very little work was left for the lower strata of the filter to accomplish. The oxidation of the carbonaceous matter was also practically completed at one foot depth, as is evident from the reduced oxygen-absorbed figure, as well as from the fact that the carbonic acid in the air of the filter nearly reached its maximum within one foot of the surface.

A remarkable increase in the free ammonia figure in the effluent from the lowest tray is recorded, and, whatever the explanation of this may be, it does not arise from an accumulation of organic solids, for, on examining the filter, no such accumulation could be detected; and this was also borne out by the ascertained percentage loss on ignition of the filter particles at different depths, as follows:—

6 inches . . .	3.25 per cent.	3 feet . . .	0.53 per cent.
1 foot . . .	0.99 „	4 feet . . .	0.53 „
2 feet . . .	0.65 „		

Possibly the phenomenon may be due to a retrograde, partially anaërobic change taking place in the bottom of the filter, arising from the combustion products in the air from the work done above.

The conclusion which the results seem to warrant is that, given fine particles and good distribution, sewage filters may be constructed much shallower than hitherto; also, if a sewage, by reason of its strength, should prove to be exceptionally resistant to treatment, more will be effected by increasing the area than by deepening the filter.

2. *Are the Preventive Measures which are employed against Infectious Diseases Effective?* By Dr. HIME.

3. *Nitrogenous Metabolism in Normal Individuals.* By Dr. J. M. HAMILL.

In view of the recent experiments by Chittenden, who has shown that it is possible to maintain nitrogenous equilibrium on diets containing relatively small amounts of protein, it was of interest to investigate the nitrogenous metabolism

of normal individuals, living in their ordinary way and performing their normal avocations. The subjects of the experiments were seven workers in the laboratory of University College. The total nitrogen and uric acid were determined in twenty-four-hour urines over a period of six days. The results are given in the following table:—

Subject	Day	Quantity of urine c.c.	Sp. gr.	Total N gm.	Uric acid gm.	Uric acid N gm.	Uric acid N \times 100 Total N
H.	1	1650	1030	20.8	1.02	0.340	1.6
	2	1700	1020	12.8	0.78	0.260	2.0
	3	1750	1018	17.8	0.77	0.256	1.5
	4	1250	1022	16.3	0.72	0.240	1.5
	5	1450	1022	17.4	0.73	0.243	1.4
	6	950	1020	13.8	0.64	0.213	1.5
P.	1*	1100	1019	9.0	0.35	0.116	1.3
	2	1540	1019	16.2	0.76	0.253	1.5
	3	1720	1018	16.5	0.79	0.263	1.6
	4	2200	1013	16.3	0.81	0.270	1.6
	5	1350	1021	14.6	0.83	0.273	1.9
	6	1900	1016	15.9	0.80	0.266	1.7
E.S.	1	1760	—	11.9	0.59	0.196	1.6
	2	1890	1013	9.8	0.50	0.166	1.7
	3	1840	1015	9.1	0.42	0.140	1.5
	4	2020	1013	9.4	0.38	0.126	1.4
	5	1660	1016	8.5	0.43	0.143	1.7
	6	1680	1015	8.9	0.37	0.123	1.4
S.S.	1	1100	1030	18.4	0.80	0.266	1.4
	2	1050	1028	15.3	0.67	0.223	1.4
	3	1520	1022	18.1	0.89	0.296	1.6
	4	1260	1020	16.5	0.82	0.273	1.6
	5	1170	1026	15.8	0.77	0.256	1.6
	6	1140	1027	15.3	0.64	0.213	1.4
F.S.	1	2100	1015	15.8	0.72	0.240	1.5
	2	1500	1017	13.2	0.55	0.183	1.4
	3	1350	1015	12.2	0.55	0.183	1.5
	4	1480	1016	13.7	0.57	0.190	1.4
	5	1160	1016	10.8	0.46	0.153	1.5
	6	1320	1016	12.3	0.55	0.183	1.5
C.	1	900	—	13.9	0.64	0.213	1.6
	2	1150	—	14.8	0.55	0.186	1.3
	3	1290	—	12.7	0.65	0.216	1.7
	4	2100	—	15.0	0.66	0.220	1.4
	5	1670	—	11.2	0.56	0.186	1.6
	6	960	—	10.0	0.46	0.153	1.5
B.	1	1140	—	11.17	0.381	0.127	1.1
	2	750	—	11.0	0.582	0.194	1.8
	3	1410	—	14.7	0.616	0.205	1.4
	4	920	—	10.8	0.638	0.209	1.9
	5	900	—	10.7	0.582	0.194	1.8
	6	1140	—	10.4	0.455	0.151	1.4

* P. 1 is incorrect, since all of the urine was not collected on that day. All the first-day values are somewhat high, owing to a heavy meal being taken before the beginning of the experiment.

Average per day for six days is given in the following table:—

Subject	Weight (kilos)	Total N	Uric acid N	$\frac{\text{Uric acid N}}{\text{Total N}} \times 100$
E.S.	60	9.6	0.149	1.55
C.	78	12.9	0.195	1.51
F.S.	74	13.0	0.189	1.46
H.	94	16.5	0.258	1.56
S.S.	68	16.5	0.254	1.54
P.	72	14.7	0.240	1.63
B.	61	11.4	0.180	1.57

Average per individual 13.5 gr. N excreted per day.

Allowing for a loss of 10 per cent. N in faeces, this is equivalent to 93 grams of protein per day.

There are several points of interest which are demonstrated by these tables. The first of these is the constancy of the ratio of the uric acid nitrogen to the total nitrogen. In five cases out of seven the deviation from the average of 1.54 per cent. is well within the limits of experimental error; in the other two cases the deviation does not exceed 0.09 per cent.

Another point of interest is the relatively low total nitrogen excreted. This is a point of considerable importance from the sociological standpoint. The following numbers are taken from Rowntree's 'Poverty: A Study in Town Life,' a study of social conditions in the town of York:—

Social condition	Amount of protein used daily *
Working-class families of total weekly earnings under 26s.	89 grams
" " " " " " " " over 26s.	119 "
Servant-keeping classes	126 "
Workhouses (including York)	136 "
Prisons. Class B	134 "
" " " " " " " " Convicts at hard labour	177 "
Atwater's standard	125 "
Average from above physiological laboratory experiment	93 "

* Calculated per adult man.

Rowntree has adopted Atwater's standard, and has concluded that 27 per cent. of the population of the city of York are living in poverty, partly on the ground that their protein diet falls below the Atwater standard. Although it cannot be claimed that the numbers obtained by us by urine analyses are strictly comparable to those given in the above table¹ (which refer to bought food), yet the differences are so great, and the actual nitrogen metabolism falls so far below the Atwater standard, that great care must be taken in drawing conclusions as to the sociological conditions from the amount of protein consumed. It is hoped that we shall be able to extend this investigation in other directions.

4. *Some Determinations of Nitrogen Excretion under Normal Conditions.* By E. P. POULTON, B.A.

The following determinations were carried out, at the suggestion of Professor Gotch, in the Physiological Laboratory of the Oxford University Museum. The object in view was to estimate about twice a week, over a period of three months, the amount of nitrogen contained in a day's urine, in order to see how far the amount

¹ It is also probable that the poorer classes take relatively larger quantities of vegetable protein, in which cases the loss of nitrogen in the faeces is greater than 10 per cent., the amount allowed for in our laboratory experiments.

of nitrogen excreted daily was liable to variation. The present writer was himself the subject of the investigation: height, 5 feet 9½ inches; weight, 149 lb.; age, twenty-two.

The day's urine was collected and its volume measured. Five c.c. were analysed by the Kjeldahl-Gunning method, the ammonia being collected in 50 c.c. of standard hydrochloric acid. The residual acid was determined by a decinormal baryta solution, the latter being standardised by potassium quadroxalate. Litmus was the indicator used. The analysis was in every case done in duplicate, and the two results generally agreed within less than 0.5 per cent. of the total nitrogen. Several blank determinations were made with the materials used for the analyses, and a small correction was made for the amount of alkali obtained in these blank experiments. The apparatus for distilling the ammonia was first of all tested by driving off the ammonia from a standard ammonium chloride solution. The amount of ammonia thus obtained agreed satisfactorily (within 0.2 per cent.) with the known strength of the solution.

Date	Total Nitrogen in Grammes	Volume of Urine in Cubic Centimetres	Remarks
April 30	16.9	1,379	No exercise
May 5	16.9	1,133	Tennis (one hour)
" 12	16.6	1,265	No exercise
" 15	15.4	954	Tennis (two hours)
" 21	18.9	1,227	Punting on river
" 29	16.1	1,710	No exercise
June 2	18.5	2,082	A little exercise
" 5	15.4	1,287	No exercise
" 10	17.7	1,005	No exercise
" 12	16.8	1,488	Tennis (one hour)
" 17	16.5	1,079	No exercise
" 25	16.1	1,465	No exercise
" 29	16.3	2,250	No exercise
July 10	15.6	1,125	Tennis
" 13	17.9	1,766	No exercise
" 17	16.8	1,277	A little tennis
" 21	17.8	1,350	A little tennis
" 24	17.3	1,546	Tennis (seven sets)
" 27	16.9	985	No exercise

The subject of the investigation lived during the period of the determinations as far as possible upon similar daily amounts of food. The diet was of the familiar type, varying in character from day to day. That of three successive days was weighed, and the amount of contained proteid was calculated from Vierordt's Tables. The total proteid in the day's food on July 27 was 122.8 grammes; this contains 19 grammes of nitrogen, and, allowing a reduction of 12 per cent. for unabsorbed nitrogen, the amount of absorbed nitrogen is 16.7 grammes. The actual excretion of nitrogen on this day was 16.9 grammes. The calculation of total proteid on July 26 gave a food intake of 94 grammes, and on July 28 a food intake of 95 grammes.

5. *Report on the Effect of Climate upon Health and Disease.*
See Reports, p. 424.

6. *Second Interim Report on the Ductless Glands.*—See Reports, p. 423.

7. *Fourth Report on the State of Solution of Proteids.*

See Reports, p. 428.

 MONDAY, AUGUST 6.

The following Discussions took place and Papers were read:—

1. *Discussion on the Physiological Value of Rest, opened by THEODORE DYKE ACLAND, M.D.*2. *The Neuron Theory: Fatigue, Rest, and Sleep.*

By Dr. W. BEVAN-LEWIS, M.Sc.

The author believes, despite the adverse views of Apathe, Bethe, Dogiel, and Donnagio, that the neuron conception has come to stay with us. After brief reference to the grounds of dissent by the above neurologists, he defined the older views respecting the constitution of the nerve-cell, contrasting it with the neuron theory as revealed by modern microscopic technique. He discussed the disposition of neuro-fibrils and the probable course of nerve-currents therein, alluding to the views of Berkeley and Cajal on the synapse. The law of dynamic polarisation enunciated by Cajal is, in the author's opinion, *not absolute*. He would regard the neuro-fibrils as possibly stimulated from two sources: (a) From their termini in the gemmules, forming an apparatus for *isolated* stimulation; (b) in the mesh-works within the cells, by products of cell metabolism, possibly by nuclear influences, and certainly by toxic agencies entering the cell from without—a mechanism for more *massive* results. Contrary to Sir W. Gowers, he still inclines to regard the cell as a storehouse of energy, and emphasised the importance of the chromophilic material of Nissl in cell metabolism, and, as suggested by Marinesco, as serving to increase the potential of the nerve-current. Lugaro's elaborate work, which supports the view that the nerve impulse originates as the result of a physico-chemical process at the synapse was alluded to. He proceeded to indicate how bodily fatigue and mental fatigue is correlated, and the fallacy of the view that gymnastics are not restoratives for *mental* fatigue. In defining the nature of the change found in the nerve-cell after fatigue, he alluded to the rôle of the 'scavenger-cell.' Waiving the several less secure theories of sleep he discussed Duval's theory of dendritic contraction, based on the known features of cell amoeboidism. Personally he dissents from this view of dendritic contraction, but favours that of gemmule retraction alone; and differs from Lugaro in regarding their *expansion* as the incident of active mental states, and *not* their *recession* as taught by that neurologist. Apart from terminal arborisations and their synapses, a further apparatus for originating the nerve impulse is found in the functioning of contiguous dendrites of separate neurons—a view which he bases on histological details of the neuro-fibril structure—and he lays great emphasis on the fixed anatomical juxtaposition of nerve-cell groupings. Dealing with brain-fag in school children he concluded by postulating the following conclusions:—

(1) The necessity for recognition of diurnal variations in the tide of mental acquisitiveness.

(2) The study of the fatigue-curve and the importance of interpolated periods of rest in its modification.

(3) The residual fatigue should be watched for if not compensated for by the previous night's rest.

(4) The enormous metabolic activity of this period of the child's life should always be borne in mind.

(5) The importance of the central nervous system as the controlling factor in general metabolism.

(6) The great developmental wave which sweeps over the psycho-motor centres at this period.

(7) The indications of degeneration of the anatomical units posited as characterising the psycho-motor cortex, as *histologically* defined.

(8) Illustrations of degeneration from want of rest and sleep resulting in special forms of mental derangement.

(9) Ten hours' sleep should be claimed as a fit allowance for growing boys and girls subjected to scholastic training.

(10) Reference was made to Sir Lauder Brunton's views of the motor centres (in a restricted sense) forming the basis of the social unit.

3. *The Hæmatology of Carbon Monoxide Poisoning.*

By G. G. NASMITH, M.A., Ph.D., and D. A. L. GRAHAM, M.B.

Guinea-pigs living for months in an atmosphere of dilute carbon monoxide, so that the blood becomes partly saturated with this gas, show an increase in the number of erythrocytes and hæmoglobin; the rise is directly proportional to the extent of the saturation of the blood. When, for instance, 25 per cent. of the hæmoglobin is united with carbon monoxide this increase amounts to 16 per cent. of the hæmoglobin and 33 per cent. of the number of erythrocytes, and is attained within a month. With 45 per cent. of the hæmoglobin saturated the increase of the erythrocytes amounts to 50 per cent.

The initial effect of the gas is to cause degeneration of the erythrocytes, associated with a marked leucocytosis of the oxyphile granular forms. The extent of the degeneration and the degree of the leucocytosis is again directly proportional to the strength of the gas employed; this leucocytosis corresponds closely with that of an ordinary toxæmia.

We conclude that the action of carbon monoxide on the body is due entirely to its ability to deprive the tissues of their normal oxygen-supply, as pointed out by Haldane. The physical and physiological effects are very similar to those produced by high altitudes. The ultimate effects on the body we consider to be due to deranged anabolic and katabolic activity in the body cells, resulting probably in the accumulation of excretory substance and the formation of toxic degeneration products.

4. *On the Mechanism of the Locked Jaw of Tetanus.*

By Professor SHERRINGTON, F.R.S., and Dr. ROAF.

TUESDAY, AUGUST 7.

Joint Discussion with Section B (Chemistry) on the Factors which determine Minimal Diet Values. Opened by Dr. F. GOWLAND HOPKINS, F.R.S.

The following Papers were read :—

1. *The Electrical Resistance of the Tissues.* By Dr. DAWSON TURNER.

How measured in the case of the blood, urine, ascitic, and other fluids. Observed and specific resistance. Difficulty of measuring the resistance of the blood, owing to the small quantity obtainable; the apparatus used.

Table of the specific resistances of some of the tissues.

Importance of measuring the resistance as an aid to diagnosis and prognosis in disease (alterations in pneumonia, diabetes, pernicious anæmia, &c.), and as a means of measuring the time between the ingestion of salts and their appearance

in the blood, urine, milk, &c., and of thus comparing the functional activity of organs. Cryoscopy, osmotic pressure, and electrical resistance.

2. *Observations on Hue Perception.*

By F. W. EDRIDGE-GREEN, M.D., F.R.C.S.

If a small portion of a spectrum be isolated by means of shutters in the eyepiece of a spectroscope, it will be found that when it has a certain magnitude it appears monochromatic. The size of this monochromatic patch varies according to the portion of spectrum which is being observed and with different persons.

The perception of hue is least at the ends of the spectrum, and then in the green in the region which possesses no 'complimentary' within the spectrum.

In some cases the perception is best in the blue region, in others in the yellow.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION.—Professor F. W. OLIVER, D.Sc., F.R.S.

THURSDAY, AUGUST 2.

The President delivered the following Address:—

The Seed, a Chapter in Evolution.

As the subject of the first portion of my Address I propose to consider the place of the seed in the evolutionary history of plants. The seed-character is the distinctive mark of three great groups of plants—the Pteridosperms, Gymnosperms (including Cordaiteæ), and Angiosperms. Nor will it be seriously questioned that the possession of this organ has given supremacy to seed-bearing plants over groups not thus characterised in a majority of the types of environment where vegetation is able to exist. Exceptions, of course, there are, though few of them are wholly immune from the invasion of the Spermophyte. The sort of habitat, for instance, in which *Zostera* flourishes—sometimes to the exclusion of other forms—is held more as a result of vegetative aggressiveness than in virtue of any special power still conferred by the seed-habit.

Our stock of knowledge of those plants which had attained to the seed-bearing condition in a bygone age has undergone some extension during the last few years; the seed, too, has shed its glamour over other branches of botanical inquiry, so that no serious apology is necessary for its selection as the subject of this morning's discourse.

It is generally conceded that the primitive vegetation arose in the waters, and that with the parting of the waters and the emerging of land and continents this primitive stock of plants was sufficiently plastic to take advantage of the new conditions, throwing up successive hordes which effected a footing on the land, and in time peopled the whole earth with forms adaptable to the varying habitats and climates as they differentiated.

Of the character of these primæval aquatic types no direct information has been vouchsafed. It is a matter of inference that they possessed much in common with the green Algæ of to-day, which, living in a biologically stable medium, are commonly regarded as their nearest representatives. Be that as it may, the complexity of the life-history of existing Algæ and the frequent presence of neutral generations seem significant of the capacity of their progenitors to originate forms with sporophytes adapted to terrestrial conditions.

In our Liverworts and Mosses on the one hand and the Ferns and their allies on the other, two divergent evolutionary lines are represented, both fitted to existence upon land surfaces, but handicapped by the retention of a non-terrestrial method of effecting the sexual process. In the Bryophytes the physiological continuity and dependence of the sporophyte upon the gametophyte is preserved throughout, and it never rises above the status of an elaborate spore-capsule; whilst the gametophyte, though often reaching a complex vegetative differentiation, offering many analogies with the sporophytes of higher plants, is condemned to pigmy dimensions through the incubus of the inherited aquatic mechanism of fertilisation.

Though remote from the series that have culminated in seed-plants, the Bryophytes are a group offering many an instructive parallel with the main series of plants; certainly these forms have remained too long a thing apart. Haberlandt and Goebel have shown us—to name no others—how happy is the hunting-ground which the Bryophytes provide. Further work is still required, directed more especially to certain important points in the life-history.

With the regular vascular cryptogams the relations between the stages are of course different. Here we find large complex sporophytes holding the ground, but hampered by the ever-recurring necessity of dependence upon outside water for the performance of the reproductive process.

The land problem was solved on ingenious lines. The differentiation of gametophytes which accompanied heterospory rendered possible the retention of the larger spore and female prothallus. Thus retained aloft, the drawback of the double existence is overcome and the advantages of the elaborated sporophyte more fully realised. The water conditions are brought directly under the plant's control through the device of the pollen-chamber, and the way paved for the ideal seed with siphonogamy.

All the elements of the seed were present before, but combined compactly in this new way we recognise what is virtually a fresh stage intercalated in the life-history. Further elaboration came bit by bit as the possibilities were successively realised. With the evolution of the seed, the plant rose at a bound to a higher plane, and this structure in its perfected form has become the very focus of the plant's existence.

The case of *Cycas* and *Ginkgo* with motile sperms affords an extreme demonstration of the inertia of heredity, the persistence in living seed-plants of the original aquatic flagellate type.

Obsolete as they are and faced with extinction, these survivors from the middle epoch of the world's history still hold their ground in a few scattered localities. In this connection we shall listen with interest to Professor Pearson's account of the *Encephalartos*-scrub of South Africa which is to occupy us during the course of the present sitting of the Section.

How the sperms became replaced ultimately by the passive cells of the pollen-tube we have no knowledge.

If the conjecture be well founded that the change came late rather than early, then the conservatism of the spermatophytic line in this respect stands in marked contrast to the adaptability that is so characteristic of another phylum of aerial plants. The ready evolution of siphonogamy in the form of fertilising tubes, so common in the Fungi, perhaps finds its explanation in the close filiation of this group with primitive and plastic forms. The fertilising tube may reasonably be regarded as a special case of a general susceptibility to chemiotactic stimuli which distinguished the whole hyphal complex of the group from very early times. In the case of the spermatophyte, on the other hand, the motile spermatozoid seems to have persisted through a long and complicated ancestral history, so that its elimination may have been less easy of achievement.

The seed, once evolved, became the centre of a host of accessory organs, constituting what we know collectively as the fruit and flower. By these it has been robbed, as we shall see, of many of its pristine functions, whilst at the same time it has undergone marked structural reduction. In the highly elaborated Angiosperm more especially we find an almost stereotyped uniformity in seed-structure contrasting with an infinite diversity in the outward floral husk.

In attempting a sketch of the origin of the seed one has to admit at the outset that recent discoveries bring us no nearer to its prototype than we were a decade ago. For the seeds of the Pteridosperms are advanced structures recalling quite vividly the type long familiar in living Cycads. It would be overstating the case to say they have nothing primitive about them, but there is a long chapter in evolution to be deciphered before we can connect, say, the seed of *Lyginodendron* with the sporangium of any Fern at present known to us.

The great interest of the recent correlation of seeds with Coal Measure plants lies less in the structure of these correlated seeds than in the very extensive series

of plant-remains which we have thus come to recognise as belonging to the earlier Spermophytes.

For the position of these plants had remained in suspense. The elaborate anatomical investigation which their vegetative organs had received at the hands of Williamson, Scott, Solms-Laubach, and others showed them to occupy a transitional position between the Ferns and Cycads. In certain respects they showed an advance in the cycadian direction, whilst in others they were wholly fern-like. Their fructifications were unknown, and their nature remained an open question. It was for this group, or series of transitional groups, that Potonié proposed the appropriate name of *Cycadofilices*.

We know now that the *Lyginodendrea* and *Medulloseæ* bore seeds attached to their fronds. The seeds have been found attached in some cases to reduced fronds consisting of a branching rachis, in others to fronds of the normal filicinean type. Indeed, so far as habit is concerned, these plants may rightly be described as seed-bearing Ferns.

As such, indeed, most people will be content to regard them—as forms, that is, having close filicinean relationship in which the reproductive method has been profoundly modified, the internal anatomy to a less extent, and the habit hardly at all. Had these Pteridosperms come to light during the lifetime of Hofmeister, that master of morphology must have pounced upon them as furnishing an important link in his chain. These fossils and the spermatozoa which the Japanese botanists discovered in the seeds of *Cycas* and *Ginkgo*, indeed, afford the most convincing direct evidence of the soundness of the Hofmeisterian scheme that it is possible to conceive. Nor is that all. For by confirming the indications first revealed by the earlier investigation of the vegetative anatomy, the Pteridosperms have afforded us a striking object-lesson of the value of the anatomical method—of the significance of purely anatomical characters too long ignored by the systematist.

Not so long ago, when new examples of these Pteridosperms were turning up on every hand, some pessimists were inclined to wonder whether, after all, any groups of real Ferns existed in the Palæozoic rocks. Such sporangia as were known might well be the pollen-sacs of seed-bearing plants. All doubts on this score are happily set at rest by the detection of germinating Fern-spores in contemporary beds. Nor can I think of any more fitting tailpiece to the investigations which lead the way to the Pteridosperms than the discovery, by the same investigator, of the antidote to these rather disturbing views. However, it is needless to dwell further on these matters now, in view of Dr. Scott's address to-morrow upon the Present State of Palæozoic Botany.

But to return to the history of the seed. In the absence of direct evidence, one can only conjecture that some old generalised type of sporangium formed its prototype, something substantial, on the lines of a *Botryopteris* or *Zygopteris*, perhaps. The heterospory that was the precursor of the seed-like condition must have been a transient phase, or else it is lost in the pre-Carboniferous obscurity. Be that as it may, the passage from the dehiscent to the indehiscent monosporal megasporangium finds its analogy in every group of plants. Where there is extreme numerical reduction of the contained structures—be they spores or seeds—a multitude of cases in the Fungi, in the Algæ, and the angiospermic flowering plants show that dehiscence tends to become obsolete. The failure to dehisce does not appear to be directly correlated with any mechanical difficulty in ejaculation. It is more probably one of those obscure cases of interdependence of phenomena in which the vegetable kingdom abounds. A special investigation directed to the elucidation of this point might be expected to yield interesting results.

We now come to the consideration of a most characteristic organ of the seed—the pollen-chamber. This cavity arises at the apex of the megasporangium, above the big megaspore, and is found in all the Palæozoic seeds, with the sole exception, so far as I am aware, of the 'seed-like' structures in *Lepidocarpon* and *Mindesmia*. The utility of the pollen-chamber is manifest, but its antecedents are quite unknown. Upon such a structure as this may have depended the success of the seed-method at a critical stage in its evolution. In the viviparous Selaginellas,

described some years ago in America, the archegonium on the prothallus of the retained megaspore is fertilised by sperms liberated from microspores which become caught in the lips of the open megasporangial wall. This analogy suggests to us that the pollen-chamber cavity may be a relic or modification of the original place of dehiscence. If this conjecture be true, we have here what was once an exit-pore converted to the purposes of ingress, just as we find, in so many Thallophytes, tubes and beaks, once, as it is supposed, the orifices of zoospore discharge now serving for the reception of male gametes.

A great feature in the early seed types was the complexity of the integument, and this still holds good in recent Cycads and some other Gymnosperms. Protective envelopes are so commonly associated with reproductive organs, and the nutritive conditions are so favourable to their production, that a naked nucellus strikes one as anomalous. If future research confirm the supposition that the Ferns which stand in possible relation to early seed-plants were ex-indusiate, like the Marattiaceæ, recent and fossil, then no doubt the seed-coat is a new formation, having no true homology with, but merely homoplastic resemblance to, ordinary Fern-indusia. The only case of a naked nucellus that recalls itself is the rather mysterious instance of *Lepidocarpon* in which Dr. Scott reports the not infrequent occurrence of non-integumented megasporangia with the prothallus fully developed.

The robust nature of the seed envelope, which was often drupaceous, is in complete harmony with the whole character of the seed if you regard the habit at its inception as a xerophilous adaptation. And such no doubt it was, an improved method whereby the plant became independent of chance water at a very critical stage in the life-history. Some of the peculiarities of fossil seed-coats, especially the ribbing of the *Lagenostomas* and several other genera, have been attributed to the multiple origin of this structure, at any rate in some cases. The remarkable circlet of tentacles which surrounds the summit of *Lagenostoma physoides* (best known by Williamson's earlier name *Physostoma elegans*) suggests that a number of foliar lobes have been incorporated in the seed, whilst the presence of perimicropylar ridges and the septate canopy in allied forms may be taken as only a less evident indication of the same thing.

The relation between the integument and sporangial body of recent Gymnosperm seeds is found to be an inconstant character, and the same is true of the fossils. In general character the relationship recalls that which obtains between the ovary and receptacle of an Angiosperm. Whilst the *Lagenostomas* resemble *Cycas* and *Pinus* in having the integument free at the apex only, *Taxus*, *Phyllocladus* and *Araucaria* are in agreement with the *Trigonocarpons* and other seeds, which are generally attributed to *Medulloseæ*, in having an integument which rises freely from the chalaza. It is interesting to note that the fossil seeds of the latter group show an additional complexity in the wall of the nucellus. For in them a series of tracheal strands or even a mantle of tracheides is found running up from the chalaza to the pollen-chamber. It is evident that nothing was spared in these older seeds to ensure adequate access of water to the pollen-chamber where the sperms must have been liberated.

In due time the protective sheath, or testa, appropriated other functions supplementary to that of protection. Of these the most important must have been the reception of the pollen. A very striking feature in all the *Lagenostomas* is the way in which the tip of the nucellus (where the orifice of the pollen-chamber is situated) projects beyond the integument. In these seeds the microspores had direct access to the pollen-chamber without first descending a micropylar canal.

In the *Medullosean* seeds also the nucellus is distinguished by a long beak, as Dr. Scott and Mr. Maslen have shown recently for *Trigonocarpon*, and, as we know, in *Stephanospermum*, and many other cases. So far as we know, this beak does not extend to the surface, though it engages with the micropylar canal, and is continued some distance up.

Though it can hardly be supposed that the long beak has been inherited from the ancestral sporangium, its presence may be none the less significant of what took place when the seed method was initiated. The direct pollination in

Lagenostoma may well be a survival from the old days when no proper micropyle existed. But when the micropyle closed in, the conservative nucellus would for a while endeavour to maintain direct communication with the exterior. The beak-like appendage on this view would be a new formation evolved *pari passu* with the integument.

A peculiar and distinctive, though negative, feature common to the whole range of Palæozoic seeds that have become known to us is the lack of an embryo. Occasionally small-sized seeds are met with, as in *Lagenostoma Lomaxi*, and now and then immature-looking stages, of which the best example is Renault's Cordaitan ovule, so often figured in the books. But apart from such rarities the petrifications agree in being at a stage which, in the light of recent Cycads, is to be interpreted as corresponding to the time of fertilisation. The pollen-chamber is charged with pollen-grains, whilst in good examples the megaspore is filled with a prothallus which frequently shows indications of archegonia at its upper extremity. All these specimens will be dismissed by some as abortive, and any conclusions drawn from the negative character as invalid. Without ignoring this contingency another view is, of course, possible. The normal fall of the seed may have followed pollination at a short interval, much as is reported for *Cycas* and *Ginkgo* to-day. The 'resting period' in these seeds would then perhaps coincide with the maturation of the sperms, whilst the subsequent embryonic history might have been carried through without a pause. This view gains support from the filicinean relationship, for of course the fertilised egg of a Fern continues its development without interruption. If the modification of the pteridophytic life-history that culminated in these early seeds were directed, as seems probable, to ensuring a greater certainty in bringing the gametes together under conditions favourable to their union, it would follow that the other great advantage arising from the seed-habit was of later acquisition. In other words, the ordinary seed with resting embryo was evolved by stages. There is a great lacuna in our knowledge of the early adjustment of the embryo to intraseminal existence. Whilst evidence of Palæozoic seeds with resting embryos is altogether wanting, we are confronted in the Mesozoic rocks with the Bennettitæ, all of which possess a well-marked dicotyledonous embryo practically filling the seed-cavity. It is mere conjecture to suggest that this change has been wrought in response to some climatic stimulus, though the marked xerophilous facies of many of the Mesozoic Cycadophyta seems quite consistent with such a view. Be that as it may, one cannot fail to recognise that the resting seed with an embryo marks a great advance on the Pteridosperm, an advance hardly less important to the welfare of the plant than was the earlier type of seed on the extended life-history of the filicinean prototype.

This stage of the seed-history would be of exceptional interest if we could hope to recover any morsels of direct evidence. As yet we remain in the dark as to the morphological nature of the embryonic organs, how far we are dealing with new structures produced from a protocorm, as Professor Bayley Balfour has suggested¹; how far they represent the old filicinean organs adjusted to intraseminal life. What chance there may be of the solution of this difficult problem by the application of other methods may emerge perhaps from the discussion on the phylogenetic value of early seedling characters which is to be opened next Tuesday morning by my colleagues Mr. Tansley and Miss Thomas.

Reference has already been made to the view that the seed, as we find it in the majority of spermatophytes with its resting embryo, shows definite adaptation to seasonal periodicity. It would be interesting to learn how far the seeds of plants long accustomed to uniform conditions, such as the rainy tropical forest, behave in this respect. The point does not appear to have been very fully reported on. Indeed there is a rich field for both observational and experimental work upon obscure seed-problems awaiting any one who can devote continuous attention to the subject. Is there any solid foundation for the supposed 'physiological dimorphism' among seeds according to which, as one reads in the older books, the

¹ Presidential Address, Section K, Glasgow, 1901, p. 9.

earlier ripening seeds are adapted to an immediate germination, whilst the later ones are reserved for the following spring? It may be that we have here but one more illustration of the operation of temperature as the limiting factor, but in any case the matter wants clearing up. An experimental investigation of the relations of 'albuminous' and 'exalbuminous' seeds would probably repay the trouble involved. Does any condition or set of conditions under the control of the operator exert an influence in this connection?

The mention of the early germination of seeds brings to mind the most striking instance of all—that of the tropical Mangrove, in which, as is so well known, the seed germinates on the tree, so that the young plant is extruded, and in some instances falls, from the parent free of its envelopes.

Our interest in this type of vegetation has been revived through the researches of Mr. H. B. Guppy incorporated in his recent contribution on 'Plant-dispersal in the Pacific.' This volume, perhaps the most important contribution to the biology of tropical plants that has appeared since the death of the lamented Schimper, is distinguished alike for its wealth of new observations and its engaging freshness of treatment. There is one suggestion of Mr. Guppy's concerning the vivipary of Mangroves which may occupy our attention for a few moments.

As a result of his studies in the Pacific and elsewhere Mr. Guppy has arrived at the conclusion that the Mangrove type of vegetation is a very ancient one, dating back to the times when climate was more uniform and moist than we know it to-day. The viviparous habit he conjectures to have been once very general, whilst to-day this primitive condition is making its last stand along the tropical shores. Traces of vivipary still occur among inland plants, such as *Crinum*, whilst in other cases it reappears intermittently under conditions not fully ascertained. Mr. Guppy supposes the ordinary fruiting way of plants with caducous fruits or seeds, that germinate after an interval, to have arisen by a modification of the continuous viviparous method in the sense that the seed has come to fall earlier and earlier till the stage now characteristic of practically all Spermophytes has been reached.

Piecing the data together, this seems to be the position: The earliest known seeds appear to have remained on the plant just long enough to receive their pollen; but in time, it is reasonable to suppose, the advantage of remaining longer was realised, and the fall of the seed was retarded till fertilisation was followed by the occupation of the seed-cavity by an embryo. Here in seclusion the embryo could remain until germination was convenient. Starting at the other end, our modern seed, according to Mr. Guppy, has been evolved by the gradual retention of the viviparous embryo; or, to put it in another way, the detachment of the seed has been hastened so that it falls long before germination is due.

Well, these theories fail to meet in the middle, as they should if they are to present us with an epitome of the whole seed-history. Perhaps there were troublous times in that middle epoch, so that the continuity has become obscure! Or possibly another view may be admissible of the relation of vivipary to normal seed-production. Most botanists, I take it, have been inclined to regard vivipary as the *dernier cri* in seed-history, the ultimate stage in the way of possible reproductive advance in seed-bearing methods that the higher plants have yet attained. The Mangrove process might even be conceived as the starting-point, under certain contingencies, of a whole new race of plants with life-histories complicated by fresh alternations—homologous alternations—far beyond any of which we have knowledge to-day!

Schimper and others who have given attention to the subject found no reason for regarding vivipary as other than an adaptation to special circumstances, an extreme condition that had arisen independently in several cycles of affinity. Before the contrary can be accepted a good deal of positive evidence will be needed, drawn from the non-Mangrove representatives of groups in which vivipary occurs, to show that the relationship is other than has been generally supposed. Moreover, if the viviparous habit were formerly of wide occurrence some traces of it might reasonably be expected in the fossil record. So far as can be ascertained, such have not been forthcoming, nor can I hear of any record of

recent Mangroves being preserved in this way. Seeds and embryos appear to be so uniform on the whole that it is difficult to understand how they could have passed through a viviparous phase in the later stages of their evolution.

The viviparous Mangroves, on the other hand, are full of diversity in detail, and these differences would surely have left a permanent mark had the course pursued been in conformity with Mr. Guppy's very interesting suggestion. That there is a rich field awaiting detailed investigation in connection with the fascinating subjects opened up by Mr. Guppy will be admitted by most naturalists.

In glancing back at the early seed-structures one is struck with the complexity of their organisation as compared with the relative simplicity of modern seeds. The pollen-chamber, the large elaborate integument, and the complicated vascular arrangements, so characteristic of the Pteridosperm seed, have for the most part passed away, giving place to much simpler structures. Occasional exceptions no doubt occur; the seeds of Palms have remarkable integuments, whilst those of *Magnolia*, some Aroids, Sapotaceæ, &c. show an unusual development of vascular tissue. Most astonishing of all perhaps is the integumental tracheal sheath which closely invests the nucellus of *Cassytha*.¹ Though evidence of their precise function be lacking, the fact that many of these structures belong to the tropical forest makes closer knowledge desirable. For in these localities the conditions must have long been relatively stable; thus increasing the chance that the structures referred to still perform their pristine functions. These and other cases like them need elucidation, but to the broad statement that the seeds of recent Spermophytes are organised on simple lines there can be no question. This reduction in complexity may be accounted for on two grounds. In the first place fertilisation by motile sperms has been replaced by fertilisation by pollen-tubes. Instead of sperms being discharged into an internal water-chamber upon which the archegonia abutted, the male cells are carried through soft tissues to the egg in a plastic tube.

In other spheres the like befalls. If primitive man had occasion to journey from Baker Street to Waterloo, he penetrated the forest and then swam the river; to-day his descendants are projected from the one to the other with accuracy and despatch in a subterranean passage.

Just at what stage the improvisation of the pollen-chamber gave place to the newer method we have no knowledge. Perhaps some information on this point may emerge from Dr. Wieland's exhaustive researches into the extensive Yale collections of American Cycadeoideas. For the Bennettitæ already show a simplification of the seed in certain respects; though, owing to the late stages of development usually found in European examples, this point could not be cleared up.

The other cause that must have played a prominent part in the simplification of the seed was the association with it of other structures which relieved it of a part of the original load of duties that fell to its lot. The dense heads of *Bennettites* show us this, and the same may be said of most Coniferous strobili. But the Angiospermic ovary provides the best example of a special organ inclosing the seed or ovule, affording it protection during the immature stages and also collecting the pollen. The steps by which this came about remain hidden, and any discussion of the matter is of course premature. The carpels may have been derived from reduced sporophylls or from portions of sporophylls that were more closely associated with the seeds. The cupule of *Lyginodendron* is an organ rather suggestive in this connection. One is tempted to compare it with a rudimentary ovary, playing the serviceable part of a moist air-chamber for the seed during the earlier stages of its development.

However, the origin of the fruit and of the flower, with all its manifold organs, must be left to the future: they form no part of our theme. Some day a happy discovery will yield a clue, and the reproach that we are in entire ignorance of the affinities of the dominant phylum will be removed.

The history of the seed, as I read it from the imperfect and fragmentary data that are available, has been a series of advances spread over long geological periods.

¹ M. Mirande, 'Le développ. et l'anat. d. Cassythacées,' *Ann. d. Sc. Nat.*, 9^e sér. bot., tom. ii., 1905.

The possibilities of the seed-habit were realised only bit by bit, and the high efficiency of the modern seed depends in large degree upon the close association of other structures which co-operate in its functions. No doubt the first step, the retention of the megaspore, was the most important of all; though, that this might be effective, some contrivance for the capture of the pollen-grains must have accompanied it. Later steps in the process of seed-evolution would include the adjustment of an intraseminal embryonic stage, and in time the substitution of the pollen-tube for the liberation of sperms.

Now assuming, as I think we are entitled to assume, that seeds have come into existence along some such lines as those thus crudely blocked out, there is a great difficulty in conceiving the process other than discontinuous. Every one of the stages emphasised involves the conception of something more abrupt than mere gradual variation. And there is, of course, the old difficulty confronting us as to how the organ or mechanism came to be preserved at its inception. All these difficulties vanish when it is recognised that effective variation is of the discontinuous order, and that the successive changes involved may be considerable enough to be designated jumps. Happily such views, based upon experimental results, have been formulated by De Vries in his Mutation Theory. That theory is so well known to botanists in this country that any exposition here is quite superfluous. The least thing that can be said in its support is that it is perfectly tenable. But we may go much further than that. Apart from the Theory of Natural Selection, no modern hypothesis of evolution has been so helpful or so likely to stimulate further work. The results of continued investigations in this field, now so actively pursued, will be awaited by all biologists with a keen and sympathetic expectancy. Not the least of the advantages that follow in the wake of the Mutation Theory is the shortening of the time required for the evolutionary process. As the physicist imposes a time limit to the period during which life has been possible on the earth, a working theory that reconciles the demands of the biologist with the physical limitations is decidedly reassuring. In this connection it is very interesting to note that Monsieur Grand'Eury, one of the most active and distinguished workers in the field of palæobotany, should have found data supporting the view of mutation.¹ In tracing the passage of fossil plants through great thicknesses of rock he has been impressed on the one hand with the high degree of permanence of certain forms, and on the other with the suddenness, when the moment came, with which one species passes into another.

The collection of data of this kind from our own Coal Measures appears to me a very pressing necessity in view of the rapidity with which the coalfields are being exhausted. Indeed the present is an unique opportunity which can never recur, and the chance of systematically utilising it is slipping away. Whatever view one may hold as to the expediency of making exhaustive collections of the recent flora, there can be no two opinions of our manifest duty to 'make hay while the sun shines' in the matter of the coal fossils. Regarded as systematically arranged collections showing how the plants occur in definite localities, the contents of most of our museums, as I am assured by competent authorities, are practically worthless. That innumerable specimens of the greatest value are preserved in museums may be readily conceded; but my point is that these collections have been accumulated without system, and that details of precise locality and horizon are frequently wanting. All this has to be done over again, and I believe local societies working in touch with a central organisation could do a memorable service which would earn them the gratitude of future generations and at the same time provide a fresh outlet for their energies.

To us the coal industry, with its vast resources, is a convenient mechanism for making fossil plants accessible. The colliery proprietor may be relied on to afford all reasonable facilities for the acquisition of select examples from these superabundant and embarrassing waste products. Should he incline to go further and contribute towards the modest funds necessary to carry out the undertaking worthily, he would increase the debt which science owes to industry. The

¹ Grand'Eury, *Comptes Rendus*, tom, cxlii. p. 25.

thousandth part of the revenue arising from the export-tax on coal would amply suffice for the purpose. Indeed, I can think of no more appropriate way of celebrating the abolition of that burdensome impost.

If I have dwelt to-day on the seed to the exclusion of other features, it is because I am convinced of its supreme importance. The evolution of the seed must have been one of the most pregnant new departures ever inaugurated by plants. The revelations of the last few years afford us, it is true, but the merest glimpse of the first stage reached, the rise of the Pteridosperms. The conquest of the world must have been slow then as it is now. The great forests of *Lepidodendrons* and *Calamites* were not reduced all at once to mere *Lycopodiums* and *Equisetums*. In this prolonged struggle, even if the *Lycopods* never produced a race to share the spoils, as some suppose, there is the evidence of *Lepidocarpon* that their reproductive methods underwent a certain if ineffectual modification in the same direction as their eventual supplinters. Probably the seed plants asserted themselves wherever physical changes overwhelmed old habitats. The rise and fall of the land, so great a feature in Carboniferous times, would favour the younger group. For as new ground became available for colonisation there would be opportunity of competing on at least equal terms with the effete types that cumbered the forest land. Nor should we forget that the seeds were well equipped with dispersal-mechanisms almost as varied as they are to-day.

A somewhat similar struggle is now in progress between the Angiosperms and Gymnosperms, but so slowly that we hardly notice it. A future age may have to be content to know its Gymnosperms from dwarf forms like those which the Japanese are so fond of producing in their pot-cultivations! But perhaps all calculations will be upset by the more effective intervention of the human race. On present indications the vegetation of the future should consist of cultivated crops and the weeds that accompany them; that is, unless the Chemist or Bacteriologist comes to our aid and solves the problem on other lines.

Botany in England.

I now turn to other matters. The period of twenty-five years that has elapsed since the British Association last met in this City all but includes the rise of modern botany in this country. During the middle decades of last century our botanists were occupied with arranging and describing the countless collections of new plants that poured in from every quarter of an expanding empire. The methods inculcated by Linnæus and the other great taxonomists of the eighteenth century had taken deep root with us and choked out all other influences. Schleiden's 'Principles of Botany,' which marked a great awakening elsewhere, failed to arouse us. The great results of Von Mohl, Hofmeister, Nägeli, and so many other notable workers, which practically transformed botany, were at first without visible effect.

It was not that we were lacking in men capable of appreciating the newer work. Henfrey, Dr. Lankester (the father of our President), not to mention others, were continually bringing these results before societies, writing about them in the journals, and translating books. But the thing never caught on—it would have been surprising if it had. You may write and talk to your contemporaries to your heart's content, and leave no lasting impression. The schools were not ready. No movement of the sort could take root without the means of enlisting the sympathies of the rising generation. It was only in the seventies that effective steps were taken to place botany on the higher platform; and the service rendered in this connection by Thiselton-Dyer and Vines is within the knowledge of us all. Like the former in London, so the latter at Cambridge aroused great enthusiasm by his admirable courses of lectures. Great service, too, was rendered by the Clarendon Press, which diffused excellent translations of the best Continental text-books—a policy which it still pursues with unabated vigour, though the need is, I hope, less urgent now than formerly. Already at the time of the last meeting in York (1881) a select band of Englishmen were at work upon original investigations of the modern kind. The individuals who formed

this little group of pioneers in their turn influenced their pupils, and so the movement spread and grew. It would be premature to enter fully into this phase of the movement, so I will pass on with the remark that modern botany was singularly fortunate in its early exponents.

Whenever the history of botany in England comes to be written, one very important event will have to be chronicled. This is the foundation of the Jodrell Laboratory at Kew, which dates from the year 1876. Hidden away in a corner of the gardens this unpretentious appendage of the Kew establishment has played a leading part in the work of the last twenty-five years. Here you were free to pursue your investigations with the whole resources of the gardens at your command. I suppose there is hardly a botanist in the country who has not, at some time or other, availed himself of these facilities, and who does not cherish the happiest memories of the time he may have spent there. Certainly Jodrell displayed rare sagacity in his benefactions, which included, in addition to the laboratory that bears his name, the endowments of the Chairs of Animal Physiology and Zoology at University College, London.

Sir William Thiselton-Dyer, who has so recently retired from the Directorship of Kew, had every means of knowing that his happy inspiration of founding a laboratory at Kew was a most fertile one. It would not be surprising if the future were to show that of the many changes inaugurated during his period of service this departure was by far the most fruitful.

Another incident belonging to the early days ought not to be overlooked: I refer to the notable concourse of Continental and American botanists at the Manchester meeting of the British Association in 1887. The genuine interest which they evinced in our budding efforts and the friendly encouragement extended to us on that occasion certainly left an abiding impression and cheered us on our way.

We are not forgetful of our obligations. We regard them in the light of a sort of funded debt on which it is at once a pleasure and a duty to pay interest. The dividends, I believe, are steadily increasing—a happy result which I am confident will be maintained.

But I should be lacking in my duty did I permit the impression to remain that botany is anything but a sturdy and natural growth among us. The awakening, no doubt, came late, and at first we were influenced from without in the subject-matter of our investigations. But many lines of work have gradually opened out, whilst fruitful new departures and important advances have not been wanting. We still lean a little heavily on the morphological side, and our most urgent need lies in the direction of physiology. As chemists and physicists realise more fully the possibilities of the 'botanical hinterland,' one may expect the conventional frontier to become obliterated. As Mr. F. F. Blackman has pointed out in a recent interesting contribution,¹ the chemist's point of view has undergone a change with the growth of the science of physical chemistry, and is now much more in line with that of the biologist than was formerly the case. This natural passage from the problems of the one to those of the other should be the means of attracting into our body recruits possessing the necessary equipment to attack physiological problems.

As the position gains strength on the physiological side, it will become possible to render more effective service to agriculture and other branches of economic botany.

This is of importance for a variety of reasons. Among others it will bring public support and recognition which will be all for the good, and it will provide an outlet for our students. It will also afford unrivalled opportunities for experiments on the large scale. Even should the economic conditions, which compel us to import every vegetable product, continue to prevail in this country, this will not be so in the Colonies. As time goes on, one may reasonably expect an increasing demand for trained botanists, ready to turn their hands to a great variety of economic problems.

¹ 'Incipient Vitality,' *New Phytologist*, vol. v. p. 22

From this rough sketch we see that the prevailing school of Botany has arisen very independently of that which preceded it. The discontinuity between them you might almost call abrupt. All through the middle parts of the last century we were so busy amassing and classifying plants that the great questions of botanical policy were left to solve themselves. Great herbaria became of the order of things: they received Government recognition, and they continue their work apart. Those who built up these great collections neglected to convince the schools of the importance of training a generation of botanists that would use them. The schools were free, and they have gone their own way, and that way does not lie in the direction of the systematic botany of the herbarium. So long as this tendency prevails the herbaria must languish. When I say languish, I do not mean that they will suffer from inefficient administration—their efficiency probably has never been greater than at the present time. But the effort involved in their construction and upkeep is altogether disproportionate to any service to which they are put. Work, of course, comes out of them; it is no question of the devotion or ability of individuals. It is the general position, the isolation of systematic botany, to which attention should be directed with a view to its alleviation.

If things are left to take their course there is the fear of atrophy through disuse. The operation of the ordinary economic laws will no doubt serve to fill vacancies on the staff as they arise, but the best men will be reluctant to enter. Of course the pendulum may begin to swing the other way, though no indication of such a change is yet apparent.

Let us now attempt an analysis of some of the causes which contribute to this condition of affairs.

In the first place, our two national herbaria (Kew and the British Museum) stand apart from the ordinary botanical current. They are administered, the one as a portion of the Kew establishment under the Board of Agriculture, the other as a department of the British Museum under a Board of Trustees. Neither has any connection, direct or indirect, with any university organisation. The Keepers and Assistants as such have no educational functions allotted them; I mean positions in these herbaria carry no teaching duties with them. There are no facilities for teaching; there are no students. No machinery exists for training recruits or for interesting anybody in the ideals and methods of systematic botany. A recent event illustrates my meaning better than any words. My friend Dr. Rendle accepted the Keepership of the Botanical Department at the British Museum a few months ago. Previously, as Assistant, he had held a lectureship at a London college. One of the first consequences of his new appointment was his retirement from the teaching post. Now that was bad. Under the conditions which one would like to see there would have been no resignation. On the contrary, the Keepership should have entitled Dr. Rendle to promotion to a full professorship. I do not mean a great post, with elementary classes, organisation, and so on, but one in which he would be occupied with his own branch, giving a course for advanced students, let us say, once a year during the summer months. Nor is that all. Such are the vagaries of our university organisation in London that we run some risk of losing Dr. Rendle from the Board of Studies in Botany. Automatically he ceases to be a 'recognised teacher,' and unless some loophole can be found the connection will be severed.

Next we come to the question of routine duties. These are heavy in herbaria, and must include a great many that could be satisfactorily discharged by handy attendants. As in the case of those who work in laboratories, half a man's time should be at his own disposal for original investigations. It is important, for a variety of reasons, that the members of the staff should take a leading part in advancing systematic botany.

Then there is another way in which a great economy could be effected in effort, time, and money. This is the transfer of the collections and staff of the Botanical Department from the Museum to Kew. This is a very old proposal, first seriously entertained some fifty years ago after the death of Robert Brown. There must be endless files of reports and Blue Books in official pigeon-holes dealing with

this question. The most recent report of a departmental committee is known to all interested in the matter. From the character of the evidence tendered it is not surprising that no action has been taken. I am at a loss to find any adequate reason for the continuance of two separate herbaria. It has been urged, no doubt, that botany would suffer if unrepresented in the Museum collections at South Kensington, and that the dried collections and herbarium staff are a necessary adjunct to the maintenance of a botanical museum. But there is little force in the contention. The specimens that go to make a herbarium are not proper subject-matter for museum display; nor is there anything about herbarium work which intrinsically fits the staff to engage in the arrangement of museum cases. The function of a botanical museum is to interest, stimulate, and attract. It should convey an idea of the current state of the science, and particularly of the problems that are to the front, in so far as it is possible to illustrate them. It requires a curator with imagination and ideas, as well as an all-round knowledge of his subject. He must also be an artist. Logically there is no reason why a museum should be part of the same organisation as systematic collections. There is, indeed, a danger of making the museum too exhaustive. I am speaking, of course, of a teaching museum, which belongs really to the province of a university, or university extension if you like. Systematic collections kept exposed under glass are luxuries. All the world agrees that the museum side is admirably done at South Kensington, and most people attribute this success to the systematic element which is paramount behind the scenes. But, as we have seen, this is a fallacy, and the 'museum argument' for keeping the herbarium at South Kensington may be ignored.

By the fusion of the herbaria at Kew one would look for increased economy and efficiency, more time for original work as distinguished from routine duties, and a more complete specialisation.

We now approach another aspect of the question—the newer lines that are opening up in systematic studies. Much has been said on the value of anatomical characters in classification, and it is pretty generally conceded that they ought to be taken into consideration, though, like other characters, they are beset with their own special difficulties. As Dr. Scott—who has always urged their importance—says: 'Our knowledge of the comparative anatomy of plants, from this point of view, is still very backward, and it is quite possible that the introduction of such characters into the ordinary work of the herbarium may be premature; certainly it must be conducted with the greatest judgment and caution. We have not yet got our data, but every encouragement should be given to the collection of such data, so that our classification in the future may rest on the broad foundation of a comparison of the entire structure of plants.' This passage was written ten years ago and we are still awaiting its realisation.

It is perfectly true that in the case of a recent proposal to found a new natural order of flowering plants anatomical characters find due consideration; still, on the whole, we are content to rely on the traditional methods that have been transmitted from Linnæus and the old taxonomists. So much material is always passing under the hands of our systematists that they cannot devote the time for the elaboration of a fresh method. In particular there are the new things which require docketing and provisional description. Hence, just when we ought to bestir ourselves lest we incur the reproach of being unprogressive, we live from hand to mouth, and seem content with the shadow of a past ascendancy. It is the opportunity that is lacking to systematists to develop and utilise their heritage.

I am sanguine enough to believe that much might be done by a redistribution of duties, especially if this were accompanied by the fusion of the great herbaria, to which reference has already been made. But the greatest hope, I think, must lie in the possibility of some form of alliance or understanding between the authorities responsible for the administration of the herbaria on the one hand and the local university on the other. For directly you give the Keepers or Assistants in the former a status in the latter, you place at the disposal of the systematists a

¹ D. H. Scott, Presidential Address, Section K, *Brit. Assoc.* (1896).

considerable supply of recruits in the form of advanced students possessing the requisite training to carry out investigations under direction. And if this be true of the herbaria, it holds equally in all the branches of knowledge represented in the National Museum. Really I fancy our Museum is rather anomalous in its isolation. I am confident that any understanding or arrangement that might be reached would be attended with great reciprocal advantage. Nor am I speaking without some data before me. The movement towards a closer relation between the museum and the university has already entered the experimental stage. For on several occasions during the last few years members of the Museum staff, from more than one department, have given courses of lectures in connection with the university schemes of advanced study. From all I hear, the experiment may be regarded as distinctly encouraging.

Before leaving this subject it may be appropriate to recall that the English edition of Solereder's great work on Systematic Plant-anatomy is rapidly approaching completion, and should be available very shortly. Its appearance cannot fail once more to arouse discussion as to the importance of anatomical characters. I hope the result produced may reward the devotion and labour with which Mr. L. A. Boodle and Dr. Fritsch have carried out their task.

In another and even more fundamental branch of systematic work the future seems brimful of promise. We are beginning to recognise that a vast number of the species of the systematist have no correspondence with the real units of nature, but are to be regarded rather as subjective groups or plexuses composed of closely similar units which possess a wide range of overlapping variability. That such might be the case was apparent to Linnæus, but the proof depends on the application of precise methods of analysis.

In the year 1870 our great taxonomist Bentham happened to meet Nägeli at Munich, and, as we find recorded in Mr. Daydon Jackson's interesting life, 'had half an hour's conversation with him on his views that in systematic botany it is better to spend years in studying thoroughly two or three species, and thus really to contribute essentially to the science, than to review generally floras and groups of species.' Bentham does not appear to have been convinced, for his comment runs: 'He is otherwise, evidently, a man of great ability and zeal, and a constant and hard worker.' At the time of this interview Bentham was seventy years old, Nägeli being seventeen years his junior. The views of the latter are now bearing fruit, as we see in the important results already obtained by De Vries and others, who are following the methods of experimental cultivation with so much success.

The supposed slowness of change has been a difficulty to many. This was one of the 'lions' left by Darwin in the way, and it has driven back many a 'Timorous' and 'Mistrust.' Now, as we begin to perceive, it is only a chained lion after all; a thing to avoid and pass by. The detection of the origin of species and varieties by sudden mutation opens out new vistas to the systematist, and along these he will pursue his way. It will take many years of arduous work, this reinvestigation of the species question. The collections of our herbaria form the provisional sorting-out from which we must start afresh. In the long run it may be that our present collections will prove obsolete, but that will not deter us. The scrap-heap is the sign and measure of all progress.

The garden thus becomes an instrument of supreme importance in conjunction with the herbarium, and that is another reason for the transfer of South Kensington to Kew. The resources of the latter could then be directed more fully than ever to the advancement of scientific botany, and the gardens will be revealed in a new light. For the operations and results of experimental inquiries would form a new feature, very acceptable to the specialist and public alike. And, as I am on the subject, it may not be out of place to remark that we all look forward eagerly to the time when the multifarious activities of Kew will permit the development of other features of which traces are already discernible. The arrangement of the living collections is at present based largely on horticultural convenience, geographic origin and systematic affinity, happily subordinated to an artistic or decorative treatment. In time we shall go further than that and attempt in some degree to reflect current botanical ideas in the grouping of our plants. Let me illustrate my

meaning by a good example. The Succulent House is generally conceded to form one of the most interesting and stimulating exhibits to be seen at Kew—not so much from the weird and grotesque forms assumed by the individual plants, but chiefly because here you have assembled together plants of the most varied affinity having the common bond of similar adaptations to a like type of environment. The principles that underlie the arrangement of the best sort of museum may be applied with advantage in the case of a garden, and with tenfold effect; for is not a live dandelion better than a dead *Welwitschia*? This feature, introduced as it would be with moderation and discretion, should immensely enhance the value of the Gardens both to the student and general visitor.

But to return from this digression: on the whole the time seems ripe for the new departure. Fresh lines are opening up in systematic botany that call for special provision. Now it was evident from the circumstances of the botanical renaissance twenty-five years ago that when it acquired strength some readjustment between the old and the new would have to be made. The thing was inevitable. The administrative acts of recent years all point in the same direction. The founding of the Jodrell Laboratory, the enhanced efficiency of the gardens, the great extension of the herbarium building, all help to pave the way. But more is wanted. Reference has been made to the advantages that would attend the migration from the Natural History Museum. But it is most important of all to devise a mechanism for securing a flow of recruits to carry on the work. This would follow in the wake of a *rapprochement* with the schools on the lines already sketched out. Difficulties, no doubt, will be encountered in the initial stages of a reorganisation, but these are inseparable from our bureaucratic system. A very hopeful sign is the readiness which the Government has shown in instituting inquiries in the past. That nothing has come of them may be attributed primarily to the attitude of botanists themselves. If they can unite on any common policy, there should be no serious delay in giving it effect.

The following Papers and Reports were read:—

1. *Some South African Cycads: their Habitats, Habits, and Associates.*
By Professor H. H. W. PEARSON.

The cycads of extra-tropical South Africa are confined to, and constitute a characteristic feature of, the floristic division known as the 'South-Eastern Coast Region.' It is bounded on the west by the Van Staden's Berg, situated a little west of Port Elizabeth. From this point the region follows the coast-line to the tropics; its inland boundary coincides more or less with the 3,500 feet contour-line on the southern and eastern slopes of the Stormberg-Drakensberg range, which here forms the edge of the Central African plateau.

The species referred to in the paper occur along the railway connecting Stormberg (5,300 feet) with the coast at East London, a line situated some 60–80 miles to the east of Van Staden's Bay, the western boundary of the cycad area. *Encephalartos cycadifolius* is found among the boulders of the kopjes and ridges which dominate the country. In all cases its habitat is such as to demand a high degree of adaptation to xerophilous conditions. The trunk branches freely from the subterranean portion; an isolated unbranched trunk is rarely seen. The plant attains a height of 12–15 feet and then gradually falls over to a recumbent or prostrate position. The cones, which are borne in whorls of 4–6, are thickly clothed with a very dense tawny wool. It is hoped to continue observations during the present year with a view to determining the point which normally elapses between successive conings and to investigate the influence of external conditions upon the production of cones and seeds. This species is probably exposed to a greater range of temperature than any other South African cycad. An account is given of the vegetation in association with *Encephalartos cycadifolius* and other cycads.

Encephalartos Altensteinii flourishes in sunny situations in the more open bush

or with its roots wedged in the cracks of precipitous rock-faces overhanging the rivers. The proportion of cone-bearing plants of this species was found to be much smaller than in the case of *E. cycadifolius*. In both these species of *Encephalartos* the growth of the stem appears to be monopodial; the cones are arranged symmetrically round the apex of the stem, which resumes growth after the production of the cones. Some account was given of a third species of *Encephalartos* and of the genus *Stangeria*. The paper concluded with a summary of general impressions resulting from a study of South African cycads, and with an expression of thanks to Messrs. E. E. Galpin, J. Wood, and G. Rattray for assistance afforded during the author's visit to the cycad country.

[Mr. Seward, who communicated the above paper, stated that he had recently received a letter from Professor Pearson, in which he gave an account of some observations made by a lady who lives in the cycad country on the growth of a male cone of *Encephalartos villosus*. On January 29 the cone was 2 inches high; on March 17 it had reached a length of $9\frac{1}{2}$ inches and a sweet odour was noticed. On May 3 the sporophylls were found to be well open, and the cone measured 20 inches; the smell had become decidedly unpleasant. On May 5 the cone was $21\frac{1}{2}$ inches high, and the smell was horrible. On this date some small beetles were caught among the sporophylls with thousands of pollen grains adhering to their slender 'probosces.' The facts observed appear to afford good evidence in favour of the view that *Encephalartos* is pollinated by insect agency.]

2. *Interim Report on Research on South African Cycads.*

See Reports, p. 431.

3. *The Vegetation of Teneriffe.* By HUGH RICHARDSON, M.A.

The author called attention to the accessibility of this island and its interest to botanists.

Factors influencing plant life are: (i) a porous volcanic soil; (ii) a low rainfall (14 inches); (iii) sub-tropical temperature; (iv) isolation.

The very marked zones of vegetation between the sea-level and the peak (over 12,000 feet) were noted by Humboldt and by Piazzi Smyth. This stratification appears to depend on the dryness of the air as well as on temperature.

Photographs and lantern-slides of the vegetation have been deposited with the Botanical Photographs Committee (Nos. 278-302).

Living plants from Teneriffe were on view in the greenhouses of the British Botanical Association in York.

The flora of the island has been described in detail by H. Christ in German, and enumerated by F. Sauer in Latin. English readers will find Sir Daniell Morris on 'Plants and Gardens of the Canary Islands' in vol. xix. of the 'Journal of the Royal Horticultural Society.'

The vegetation of the nearly level commons near York is in instructive contrast with that of Teneriffe. Here there are as many zones of vegetation in 12 feet of vertical height as in 12,000 feet in Teneriffe. For instance, *Erica Tetralix* occupies a very marked horizontal zone, intermediate between grass and heather. In this case soil-water content is suggested as the determining factor.

4. *A Preliminary Investigation into the Metabolism concurrent with Heat Production in some Aroids.* By MISS C. B. SANDERS.

In connection with some histological work done last year by Dr. Church in the Oxford Botanical Laboratory on the heat-producing tissues of *Arum italicum*, I undertook a small series of observations of temperature in that species and *Dracunculus vulgaris*, both *in situ*, on the plants, and with cut specimens.

The somewhat variable results and some hitherto unrecorded sudden variations made it seem desirable to investigate anew into the phenomena involved.

It will be seen that the work was not a repetition of that of Kraus and Garreau, as it involved the direct estimation of the gaseous interchange; both CO₂ and O₂ (no other gases being demonstrated) were simultaneously ascertained. This was possible with Dr. Haldane's apparatus for gas analysis.¹ This part of the work was done under his guidance.

The temperature was ascertained by two methods; for the ordinary rise the surface temperature was taken with a number of delicate thermometers (five) which could be read together within the required range; they were graduated to tenths of a degree Centigrade. Further data as to internal temperature and local oscillations were obtained with the thermopile.

It was difficult to obtain the necessary material in sufficient quantity; the Cambridge Botanic Garden furnished a number of valuable samples, which made it possible to give some details of heat-rise in three species not formerly experimented with—*Helicodiceros muscivorum*, *Arum elongatum*, *Colocasia antiquorum*, var. *Fontanesii*—as well as *A. italicum*, *A. maculatum*, and *D. vulgaris*.

The whole work was carried out in the Oxford Physiological Laboratory, owing to the kindness of Professor Gotch, who himself directed the work.

Results.—The supposition that no truly normal results of gaseous interchange are to be expected in experiments carried on in confined air seems to be confirmed by the fact that a current of air falling below a minimum of 30 cc. per minute produced sudden depressions of the rising temperature. Further, the sensitiveness of the plant at this time was seen in the sudden local rise of temperature on wounding—2° C. to 35° C. (conducted upwards as much as 5 to 6 mm.), with a fall lasting over three to seven minutes; and, further, in the fact that no plant under experimental conditions showed the maximal rise as compared with outdoor specimens.

The diurnal recurrence of heat production was noted only in a few specimens of *A. maculatum* and of *D. vulgaris*. In *A. italicum* it appeared only associated with an artificial disturbance of the process of starch combustion. The gaseous interchange seems to follow exactly the rise and fall of the local heat production, which appears to be quite independent of external temperatures (within normal limits) or of light, and coincides with the protrusion of the stigmatic hairs.

The maximum rise of the gaseous interchange is rapidly attained, the highest noted being a production of 2.97 c.c. of CO₂, with an absorption of 3.08 c.c. of O₂ (calculated at 766 mm. mercury pressure 0° C.).

The respiratory quotient varies considerably, but except after the first sudden drop in the gaseous interchange is always less than 1; at that point in some cases respiratory quotient 1, or even 1.2, has been noted. Over the subsequent slow subsidence of the interchange more O₂ is again absorbed.

Extracts from the spadices of three species gave indications of the presence of a number of enzymes; it is intended to investigate these as soon as material is available.

5. *Report on the Registration of Botanical Photographs.*

See Reports, p. 433.

6. *Report on Peat Moss Deposits.*—See Reports, p. 430.

¹ See *Journal of Hygiene*, January 1906.

7. *Second Interim Report on the Structure of Fossil Plants.*
See Reports, p. 432.

8. *Ecological Work in Switzerland.* By Dr. T. W. WOODHEAD.

Swiss botanists early recognised the fundamental principles of geographical botany. Simler in 1633, and Scheuzer in 1706 and 1708, had already begun to speculate on the environmental conditions of alpine plants, and in 1768 Haller gave the first sketch of vertical zones of vegetation. A few years later (1822 and 1825) Kastofer published excellent observations on the influence of climate and man on forests, their former and present limits, and hints on replanting. Hegetschweiler (1831) studied the plasticity of plants, and made experiments and observations on the effect of environment on plant form. In 1836 Heer published an excellent study of the flora of part of Canton Glarus, dealing with climate, soil, vertical zones of vegetation, and habitats. Since then studies of small areas from an ecological as well as from a floristic point of view have been largely followed and extended, especially in the botany schools of Zürich, under Professor Schröter, and in Geneva by Professor Chodat and Dr. Briquet. Christ's 'Pflanzenleben der Schweiz' (1879) marked a new era, and, except for formations and adaptations, is a complete geo-botanical monograph of Switzerland. In the quarter of a century following its publication some three hundred books and papers have appeared in Switzerland dealing with various branches of the subject. The following groups will serve to illustrate the range and extent of this work:—

History of the Flora.—The names of Christ, Schröter, Heer, Briquet, and Jerosch are conspicuous in this direction. Jerosch's history and origin of the alpine flora is an able work. Schröter has given a complete account of the post-glacial history of vegetation in Northern Switzerland, while Heer, Schlatter, Walser, Neuweiler, and others have dealt with the history of cultivated plants.

Forestry occupies an important position in the economy of the country, and the literature is very extensive. An exhaustive work on the forests of Switzerland is now in progress, by Coaz and Schröter, which will occupy some twenty volumes; this is being issued by the Forestry Department.

Pasture and Meadow Vegetation has been studied in a very detailed manner by Stebler and Schröter; the results have been published by the Agricultural Department, the volumes being sold to students at a nominal price.

Moorland and Peat Studies were placed on a solid foundation by Lesqueraux in 1844–47, later work culminating in Früh and Schröter's admirable 'Moore der Schweiz.'

No systematic attempt is being made to treat uniformly the phytogeography of Switzerland, but many selected areas have been treated in detail by Schröter and his students, Chodat, Briquet, and others; as well as the more general works of De Candolle. Several important papers are being published, notably those of Brockmann and Brunies. Such studies receive special encouragement from the Agricultural and Forestry Departments, which also carry on numerous investigations on soil, phenology, &c.

Vegetation of the Lakes has received special attention, the work often being the work of subsidised Commissions, those published dealing with lakes Geneva, Constance, Katzenssee, de Brett, Lutzelsee, and the lakes of the whole Jura. Many of these are very elaborate, and treat of the chemistry, physics, geology, and fauna, in addition to Plankton, Algæ, and higher plants.

Works dealing with the *alpine flora* are very numerous, Schröter's 'Pflanzenleben der Alpen' giving an excellent account of work in this direction.

Swiss Survey Maps are well known, and a great advance on our own, such vegetation features as region of vine cultivation, grass-land, moors, moors cut for peat, forest, rocky slopes, alpine region, and snow and ice, being accurately shown.

Ecology of the Cryptogamic Flora has received considerable attention, the mosses by Pfeffer, Amman and Meylan, and the fungi by Fischer and von Tavel.

In May 1905, Dr. E. Rübel established, at his own expense and at the suggestion of Professor Schröter, a biological station at Bernina Hospiz (2,309 mètres). This is equipped with all necessary meteorological instruments, and regular daily observations are made. Much interesting work is going on here in studying the conditions of plant life in the Alps.

Commissions, aided by Government grants, play an important part in furthering ecological and other studies, the 'Naturforschende Gesellschaft der Schweiz' receiving annually about 60,000 francs for these purposes.

Excursions do much to encourage the study of plant geography and ecology, especially in Zürich and Geneva, some of these being not only in the Alps, but to distant parts of the Mediterranean region, and extending over three to four weeks. In Zürich an excursion fund exists of 30,000 francs, the interest of which is distributed to such students as need it to meet the expenses of these extended tours.

9. Succession of Plant Formations in Britain. By C. E. Moss, M.Sc.

1. The plant formation of sand dunes begins its history as an open association (a) of strand plants (*Atriplex* spp., *Salsola*, &c.), or (b) of sea couch-grass (*Agropyron junceum*), or (c) of marram grass (*Ammophila arundinacea*); passes through intermediate associations (a) of dune pasture plants (*Festuca rubra* var. *arenaria*, &c.), or (b) of dune marsh plants (*Hydrocotyle*, *Scirpus maritimus*, *Juncus* spp., &c.); and ultimately becomes a closed association of heath plants (*Ononis repens* var. *horrida* or *Salix repens* or *Calluna*). At various of its later stages it is often destroyed and converted into sandy farmland or golf links.

2. The plant formation of muddy salt marshes begins its history as an open association of *Salicornia*. It passes through intermediate associations composed of plant societies dominated by various halophilous plants, such as *Triglochin maritimum*, *Plantago maritima*, *Buda* spp., and *Armeria maritima*. In its later stages it is partially destroyed by the grazing of cattle and horses. Finally it is completely destroyed, and converted into rich grazing land.

3. Lowland peat moors often begin their history as shallow meres or lakes, at first occupied by an open association of submerged and floating aquatic plants. Later a reed swamp takes possession of the margin. The reed swamp is an intermediate plant association dominated by several species (*Phragmites*, *Typha*, *Sparganium*, &c.), each possessing the same plant form. The reed swamp invades the centre of the mere, and is itself ousted by marsh plants, such as *Sphagnum* spp. and *Eriophorum angustifolium*. The whole becomes a peat bog dominated by peat-loving plants, such as *Erica Tetralix*, *Myrica*, and *Molinia*, and finally becomes a closed association of *Calluna*. The plant formation is often destroyed by the digging of peat, by the planting of birches and pines, and by the conversion of the peat moss or moor into peaty farmland. In the hollows left by the peat-cutters the whole plant formation tends to repeat its history.

4. Upland peat moors in England are not at the present time in process of formation, and the plant formation can therefore only be satisfactorily determined by an examination of peat deposits. Mr. Lewis finds more or less definite plant successions in the peat mosses of Scotland. The author is engaged in an examination of the peat deposits of the southern Pennines, and, in his opinion, the time is not ripe for a definite pronouncement on the succession of plants of upland peat moors.

5. The difficulties in the way of forming a judgment regarding the succession of plants which has led up to the various types of primitive woodland (birch, pine, oak, and ash) are also very great, as almost all the primitive forests of the British Isles have been destroyed and converted into agricultural land, or have

degenerated into heaths or moors. In several limestone districts, however, the author has, in his study of ash woods, observed the following successions of associations:—

(i) *At altitudes below about 1,000 feet*—(a) Limestone (or natural) pasture; (b) limestone heath; (c) copse of hawthorn (*Crataegus*), hazel (*Corylus*), ash (*Fraxinus*), &c.; (d) ash wood.

(ii) *At altitudes above 1,250 feet*—(a) Limestone pasture; (b) heath pasture; (c) *Calluna* moor.

(iii) *At altitudes below 1,000 feet*—(a) Limestone screes; (b) copse of hawthorn, &c.; (c) ash wood.

(iv) *At altitudes above 1,250 feet*—(a) Limestone screes; (b) limestone heath; (c) *Calluna* moor; (d) *Eriophorum* moor at 1,500 feet.

6. In a small area like England it would appear that the plant associations are determined much more by edaphic than by climatic factors. Of the edaphic factors the occurrence of humus and humous acids is one which is highly important, and deserving of more serious attention than ecologists have yet bestowed upon it.

7. In this communication a plant formation is regarded as an historical series of plant associations, beginning as an open association, passing through intermediate associations, and finally becoming a closed association.

8. An open association is usually dominated by one plant, and the number of other species is small. An intermediate association either consists of a number of smaller vegetation units (plant societies), as in the case of the dune marsh association, or is dominated by several plants, each of which possesses the same plant form as in the case of the reed swamp. The number of species in an intermediate plant association is often very large. A closed association is again dominated by one plant, and the number of species in the association is small. The ground is not fully occupied by plants in an open association, whereas in a closed association plants cover all the available ground. Intermediate associations pass gradually into each other, but the extremes are easy to differentiate.

10. *Corn Smuts and their Propagation.* By Professor T. JOHNSON, D.Sc.

The author described the important results obtained by Brefeld in his investigations of the mode of propagation of the smuts.

1. Kühn's observation of the infectibility of the oat seedling holds good. The fungus reveals itself in the same season by its dark spore masses in the oat inflorescence.

2. Brefeld shows that in wheat and barley the seedling is not attacked. The smut spores reach healthy plants by the aid of the wind, and gain entrance through the flowers. The fruits of such infected plants appear healthy in the harvest, but in the following season give a smutted crop in artificial cultures, even to totality of infection.

3. Thus, while fungicides and rotation of crops are effective means of protecting oats, fungicides are useless against barley and wheat smut. The seedlings are immune to attack, and the fungicides do not reach the internal mycelium. Safety lies only in securing seed from healthy crops.

4. The writer suggested the use of the term 'heterositic' in speaking of the smut fungus, by contrast with the term heterocœious as applied to the rusts. Thus in oat smut the fungus lives saprophytically in a nutritive solution, and reproduces itself abundantly in the formation of secondary conidia, or 'sporidia.' Later the fungus lives parasitically in the oat plant, and here reproduces itself by the production of the smut spores or chlamydo spores. Each different kind of food-supply has its associated spore.

11. *Some Injurious Fungi found in Ireland.*

By Professor T. JOHNSON, D.Sc.

The writer gave an account of (a) two cases of potato-scab, due to *Spongospora Solani*, Brunch. (in which he had found the plasmodium stage), and to *Sphondylium atrovirens*, Harz, the conidial stage of *Phellomyces sclerotiphorus*, Frank.; (b) leaf-brown or dry-spot of the potato-plant, due to *Sporidesmium Solani varians* Vañha, and as far as time allowed of other diseases in the cereal, fodder, and garden crops, of which specimens had been received from the instructors and others connected with the Department of Agriculture in various parts of the country.

A map showing the present state of knowledge of the distribution of the dreaded American gooseberry mildew was shown. The steps taken to destroy the pest were also described.

12. *Six Years' Seed-Testing in Ireland.*

By Professor T. JOHNSON, D.Sc., and Miss R. HENSMAN.

The writers gave an account of the results of the Seed-testing Station of the Department of Agriculture and Technical Instruction in Ireland, the only Government station of the kind in the United Kingdom. The use made of the station is indicated by the accompanying table:—

Year.	No. of Samples tested.	Year.	No. of Samples tested.
1900-2	486	1905	1,536
1903	712	1906 (to date)	1,471
1904	1,041		

The value of the station in connection with the flax industry, as well as with agriculture in general, was indicated. The farmer is encouraged to get his seeds tested by being charged 3d. only for a sample. Samples were described in which the germination was as low as 1 to 10 per cent. Attention was also called to the impurities in seeds.

13. *Acclimatised Plants.* By W. WILSON.

We find very few such plants among the very various native flora. We also notice that there is difficulty in drawing the line as to what is wanted of an exotic plant to make it acclimatised or naturalised. We consider the point reached when those plants establish themselves in the same way as plants which have been recognised as of the British flora. The natural idea is that such plants would increase as old ones of this country diminished. But it may not perhaps be necessary that old ones disappear or decrease. We have places along the sides of streams, sands, and gravels which are open for occupation, and in which a new plant will often pave the way for another and so on. The nursery and the garden are the great seats of exotic life, giving endless chances of plants spreading from them were they adapted to do it. We see many attempts of plants to adapt themselves outside a garden, but the attempt usually ends by some plant or plants springing up more or less abundantly, but absolutely failing to spread away through the surrounding country. This applies forcibly to native plants when taken from a place and planted in another where they are not native. And they seldom spread away from a garden. The only species which I know of which as an exotic plant has in recent times become a staple wild plant is Yellow Mimulus—*Mimulus luteus*, Linn.—which is now recognised as *M. Langsdorffii*. The question arises whether hybridising may not have taken place in this country and brought out our plant. Whether this is the case or not, the plant has spread from gardens along streams, &c., even into upland places where it has flowered and produced seed, being more or less used by animals as a food plant. We find that the fox-glove, *Digitalis purpurea*, Linn., was not noticed by early English poets; even Shakespeare does not mention it. It was first noticed in the fifteenth century as

a medicinal plant. But plants grown in this country do not seem to be good for medical purposes. I also mention *Verbascum thapsus*, Linn., a self-seeding biennial which grows in and about my garden. I saw a specimen one summer a mile and a half down the stream; this flowered splendidly, but the stem was broken down when in flower. It did not in any way indicate being a hybrid.

As regards trees or shrubs, in the fall of 1903 I had examined at Kew a specimen of a shrub growing on the moor of the original type of *Sambucus nigra*, Linn., which shows some peculiarities in flowering and in fruitbearing. Near it is *Cratægus Oxycantha*, Linn., the spot marking the limits of both in that part of the country. I had also a thornless rose pointed out to me several years ago growing at Lochaber, Alford, Aberdeenshire. At the time I looked over it I found no thorns, only a few hairs. Up to date it presents similar conditions. Mr. J. G. Baker of Kew compared it, making it a form of the North American *Rosa Virginiana* of Millar, *Rosa lucida* of Ehret, *Rosa Baltica* of Roth, which was introduced into Britain two hundred years ago, and is well figured by Dillenius in 'Hortus Elthamensis.' The shrub must have been growing there for a hundred years at least. It is situated in a rough sort of stone dyke along the end of a garden, reaching to the side of the stream. The roots may penetrate down into the rock. It grows up in the garden hedge. There are no accounts of how it may have got there. I have not seen any other quite the same, though I have one similar, so far as having few thorns is concerned, in my garden. Whether this rose had been introduced or has originated in this country is doubtful. It is either the form taken by an acclimatised rose or a species originating in this country analogous to the North American one.

FRIDAY, AUGUST 3.

The following Papers were read:—

1. *Some Aspects of the Present Position of Palæozoic Botany.*
By Dr. D. H. SCOTT, F.R.S.

The classification of the Vascular Plants of the Palæozoic period provisionally adopted may be tabulated as follows:—

Lycopsida	{	Sphenophyllales Equisetales Lycopodiales	}	Articulatæ (Lignier)
Pteropsida	{	Filicales Pteridospermeæ Gymnospermeæ	}	Spermophyta

The main divisions Lycopsida and Pteropsida, proposed by Professor Jeffrey, are employed as convenient, and, on the whole, natural, though constant distinctive characters may not be assignable. It is recognised that the distinction between Lycopsida and Pteropsida is by no means an absolute one, and the existence of a certain affinity between Sphenophyllales and Ferns, as suggested by Professor Lignier, is regarded as probable.

The Sphenophyllales are found to be a synthetic group, the representatives known to us being apparently the last specialised survivors of a very ancient race of plants, of which the Devonian Pseudobornias may give us some conception.

The near relation between the Sphenophyllales and the Equisetales is expressed by their association under Articulatæ. The Lycopods are more remote.

Both vegetative and reproductive characters indicate a definite affinity between the recent Psilotales and the Sphenophyllales, though not so close as to justify their union under a common name. The quasi-spermophytic Lycopods are regarded as a parallel development, without affinity to Conifers or to any other line of true seed-plants.

The second main division, Pteropsida, is taken to include the whole of the

seed-plants as well as the Ferns. The difficult question of the position of the Ferns in the Palæozoic flora is considered, the difficulty arising from the accumulation of evidence showing that most of the so-called Palæozoic Ferns were in reality seed-plants. The conclusion is reached that a large body of true Ferns of a simple type—the *Primofilices* of Mr. Arber—existed in Lower as well as Upper Carboniferous times, the *Botryopteridæ* constituting one special family of this group.

It is also considered probable that true Marattiaceous Ferns existed, though many of the plants hitherto classed with them were certainly Pteridosperms.

The position of the Pteridospermeæ as a distinct class of Spermophyta is considered, and the view is taken that, considering the very primitive characters which they present, it is better to keep them separate from the Gymnosperms, a class which had departed so much further from Cryptogamic traditions.

The evidence for the derivation of Pteridospermeæ from ancestors belonging to the same stock with the Ferns is found to be of overwhelming strength. Their origin, however, no doubt lay very far back, for Pteridosperms, and probably even Cordaitæ, are among the oldest known land-plants.

No great advance has been made of late in our knowledge of Palæozoic Gymnosperms. The Cordaitæ appear to belong to the same main phylum with the Pteridospermeæ, while in another direction they show distinct affinity to the Conifera.

In conclusion, attention is called to the very special nature of the floras from which our knowledge of Palæozoic plants is derived. Material from new sources is urgently needed in order to extend our data.

Recent research has been mainly carried on from a morphological point of view. It is very desirable that the conditions under which Palæozoic plants grew, and the biological character of the vegetation, should also receive attention.

2. *On the Occurrence, Distribution, and Mode of Formation of the Calcareous Nodules found in Coal Seams of the Lower Coal Measures.* By Professor F. E. WEISS.

The petrified remains of Coal-measure plants, which through the investigations of Binney and Williamson, of Scott, Seward, and Oliver, have so largely increased our knowledge of the past history of the vegetable kingdom, were chiefly contained in calcareous concretions (the so-called 'bullions') found in certain seams of the Lancashire and Yorkshire coalfields. As first described by Binney, they were to be found in three seams in Lancashire: in the 'Upper Foot' or 'Bullion' Mine, in the Gannister coal, and in a very narrow seam of a lower horizon. Some confusion, however, exists with regard to the two former seams owing to their union to form the 'Mountain Four Feet' seam, and there seems considerable doubt as to the occurrence of coal-balls in the Gannister coal. Indeed, it would seem now generally accepted that true coal nodules occur only in one single horizon (see Lomax, 'Annals of Botany,' 1902). The nodules or bullions occurring in this Upper Foot seam (correlated by Bolton with the 'Hard Bed' seam of Halifax) vary from an inch to a foot in diameter. They are concretions consisting mainly of carbonates of lime (45 to 70 per cent.) and of magnesia (10 to 20 per cent.), with small quantities of oxide and sulphides of iron. Sometimes they are so numerous as to render the coal utterly useless, and they may be found to occur over a space of several acres. They contain a tangled mass of plant remains, often in a state of excellent preservation. Shells are not found in these nodules, but are very common in similar nodules found in the roof of the seam. According to Binney the occurrence of nodules in the coal is always associated with that of fossil shells in the roof, and the nodules may therefore probably be formed by calcareous salts in solution in water, which became aggregated round certain centres in the submerged peaty mass of vegetable matter.

A similar mode of formation has been suggested for the calcareous nodules (*Dolomitknollen*), which occur in certain seams of the Westphalian coalfield,

where marine shells are found in the shaly roof of the seam. Stur has also noticed the same in the case of calcareous concretions (Sphærosideriten) in certain Austrian coal seams. These are accompanied by roof nodules (Thon-Sphærosideriten) containing the remains of marine shells.

On the other hand Mr. James Lomax has pointed out that when the calcareous nodules are very numerous, and often welded together into a single mass, neighbouring nodules do not show continuity of plant structure; which fact he suggests points to the possibility of the nodules having been carried into their present position after petrification.

To settle definitely which is the mode of formation it would seem important:

(1) To obtain as much evidence as possible from a wide geographical area, and from different horizons, of the occurrence of these calcareous concretions in coal-seams, and to note whether they are in all cases associated with a shale roof containing remains of marine animals.

(2) To examine carefully the tissues in closely packed nodules, with a view to discovering any possible continuity of structure, so as to determine whether the nodules have been formed *in situ* or not.

3. On the 'Coal-Balls' found in Coal Seams.

By MISS M. C. STOPES, D.Sc., Ph.D.

Owing to the variety of concretions and nodules found in the Coal Measures, and the many local names for them, it seems wise to describe those distinct concretions in the actual seam, containing plant structures and now well known to botanists, as 'coal-balls'; and the concretions in the roof above them containing goniatites and a few plants, as 'roof-' or 'goniatite-nodules.'

For long it has been generally accepted by those who work among the Lower Coal Measures that the true coal-balls are to be found only in one geological horizon—viz., the 'Bullion,' or 'Upper Foot' Mine.

In the course of our work, however, Mr. Watson and I have satisfied ourselves that (granted the correctness of H.M. Survey of the district, which in this case seems beyond doubt) a seam containing typical coal-balls associated with goniatite nodules, which we have unearthed, lies some distance *below* the well-known Gannister bed, while the true Bullion seam lies above it. The pit at Hough Hill which has supplied so much material seems also to belong to this lower horizon.

Further, I have evidence of very similar, if not identical, structures in the Middle Coal Measures. This shows that the factors needed for the formation of these structures have combined more than once during the deposition of the Coal Measures as a whole.

The coal-balls are undoubtedly concretions, largely composed of CaCO_3 , though varying much locally, as detailed analysis shows. They are of various sizes and often completely surrounded by coal. As a rule the plants in two neighbouring balls are disconnected fragments, but in some cases the same plant continues in two nodules. This suggests that the concretions containing the plant tissues were formed in the place in which they are now found (except for slight subsequent shifting due to earth movements).

Though this is opposed to Mr. Lomax's view, it seems to be supported by the discovery at Shore of a single calcareous mass, in the form of a number of nodules cemented together by carbonates, all rich in preserved plant remains; the whole enormous mass weighing two tons and locally replacing the coal in the seam. While further in support of the *in situ* theory, a coal-ball found in the floor of the seam contains practically nothing but stigmarian rootlets.

The constant association with the roof nodules containing marine shells suggests that the infiltration of sea-water and carbonate was necessary for the formation of the true 'coal-balls,' a view suggested by Binney; against which we have as yet discovered nothing directly militating, though we cannot give conclusive facts in its favour.

A careful survey of the mine at Shore reveals the extremely local occurrence

of the coal-balls; in twenty yards a 'pocket' may be worked through. The evidence which could be collected under the difficult conditions of underground work went against rather than in support of the view that they had been brought by streams at the time of the deposition of the coal.

Most of this work was done in collaboration with Mr. James Lomax and Mr. D. M. S. Watson, though our views do not coincide in all cases.

4. *On the Origin of Coal.* By Professor H. POTONIĆ.

We have three kinds of coal: firstly, the bright coal; secondly, the dull coal; and, thirdly, the strata coal, which is composed of layers of bright and of dull coal. Between these different coals we have all transition stages. I set aside those combustible biolithes which are pyromonimites, such as amber.¹

If we regard the *recent* combustible biolithes which have certain characteristics of coal, we have also three classes: first, the peat, which is also bright, when it is thoroughly ripe, as the 'dopplerit'; secondly, the sapropel and saprokoll; and, thirdly, the strata peat, which is a mineral composed of layers of peat and of saprokoll.

If we wish to understand the genesis of the *fossil* minerals I have named, we must compare them with the genesis of the *recent* minerals.

The sapropel is formed from the excrements and bodies of completely aquatic animals and plants which have lived in stagnant water, and therefore, because the water is stagnant, do not decay completely. Sapropel is a slime, or mud. This sapropel becomes saprokoll when it is sub-fossilised, and is then of a gelatinous consistency. Even if the saprokoll is of Tertiary age (= dysodil) it can still be gelatinous. When it is of older geological formations it is very hard—exactly like sapropel or saprokoll which has been dried in the air. In the coal measures of the Carboniferous formation this is represented by the cannel coal, which is a fossil sapropel.

Genuine coal is fossil peat. If we look at it under the microscope it has the same appearance as ripe peat, as Fr. Link, of Berlin, demonstrated in 1838. All other facts also show that the genesis of peat and genuine coal is identical. Of these facts I will mention the following:—

Very often we have under the peat-seam soils with roots, rootlets, and rhizomes, especially those of the reed-formation (*Arundo Phragmites* and other species). The same is often the case under the layers of coal from cainozoic and mesozoic formations, while under the coal seams of the Carboniferous formation we have other plants, which form these soils: I mean the well-known 'underclays' with stigmata of British miners. Often, too, we see the trunks of trees still arranged as if it were a forest—and it was once a forest. I cite as examples the trunks at Whiteinch, near Glasgow, and at Osnabrück. In the peats it is a common fact that there are forests of tree-trunks.

The same characteristics which we see in the construction of the real bog plants are displayed also by the plants of coal measures, such as the growing in stages.

The strata peat comes from places where the peat is periodically under water. This produces sapropel, which again is covered with peat when the water disappears. The coal which corresponds to the strata peat is very common.

The chemistry of the bright coal on the one side and of the dull coal on the other is very different, in the same way as the corresponding peats. The dull coal is the gas coal, and the sapropelites gives also much more gas than the genuine peat.

It will be interesting to the English, especially in the neighbourhood of Whitby, to hear that the wood transformed into a sapropelit—and to the sapropelites belong the bituminous limestones and clays—becomes jet,² which demon-

¹ See Potonić, *Klassifikation und Terminologie der recennten brennbaren Biolithe*, Berlin, 1906.

² See Gothan in the *Naturwissenschaftliche Wochenschrift*, Jena, 1905.

strates once more the chemical difference between the sapropeliferous rocks and the humous rocks.

As generally the peat is terrestrial and the sapropel is aquatic, and both are autochthonous, so the bright coal on the one side and the dull coal on the other have the same genesis. In other words, the peat and the bright coal on the one hand, and the sapropel and the dull coal (cannel coal) on the other, are derived from organisms which have lived and died *in situ* (*sur place*).¹

If we are now to say a few words on the practical side, it must be regretted that civilisation has for a long time been spoiling the peat bogs by drainage, and thus has killed them and made dead bogs which no longer produce peat. Britons especially should remember that one day they will require a substitute for coal, which is diminishing rapidly.

SATURDAY, AUGUST 4.

The following Papers were read:—

1. *Contributions to the Root Anatomy of the Cupuliferæ and of the Meliaceæ.* By W. J. GALLAGHER.

There are two distinct types of rootlet in our native Cupuliferæ:—

- (a) Rootlets free from a fungus.
- (b) Rootlets bearing an exotrophic mycorrhiza.

In (a) a root-cap, root-hairs, definite hypoderm, and cortex of upwards of twenty concentric layers are present: in (b) root-cap, root-hairs and hypoderm are absent; there are not half a dozen concentric layers in the cortex; the rootlets are much shorter than in (a). The fungus-free rootlets are clearly not roots of extension and fixation alone; they are also absorptive, as shown by the well-developed root-hairs.

Cultures of the mycorrhiza were made on various media, but all failed to give a fructification.

Meliaceæ.—Twenty-two species were examined. In some species a layer of cells with lignified but not specially thickened walls runs round the root-cap, forming an internal sheath in its substance. It can be traced onwards as a continuation of the lignified hypoderm, moving quickly, step by step, outwards when it reaches the root-cap, until it comes to lie in the last firm layer of the latter. In roots possessing this structure the conducting bundle is differentiated closer up to the root-apex than in the ordinary root. Probably the growth and elongation of such roots are arrested, but their absorptive and translocative activities continue. It is not impossible that this state may be attained in all species, though only observed in some.

Except in two species the hypoderm is suberised, and in the greater number lignified as well. In addition to the outer tangential wall, sometimes the radial wall, in whole or in part, and occasionally the inner tangential wall, are lignified. The entire cell-wall may remain without local thickening—this is rare; or the outer tangential wall may present one of two types of thickening, and the radial walls likewise two. Several species exhibit three of these types in the same cross-section. In *Cedrela Toona* Roxb., *Cedrela febrifuga* Bl., and *Swietenia Mahagoni* L., cells occur in which a thickening runs right round the radial, proximal, and distal anticline walls, looking like a large Caspary's point (ϕ -cells of Russow). In the *Cedrela* spp. the thickening is lignified, and a suberised lamella runs right round the cell.

Lenticels similar in outward appearance and anatomy to those of stem-members are found on *Dysoxylon alliaceum* Bl., but not in *D. excelsum* Bl., a species of like habit, size and anatomy. A cork layer is formed in these organs much later than

¹ See Potonié, *Entstehung der Steinkohle (Formation de la houille)*, Berlin, 1905.

in the adjacent hypoderm. Probably they (1) are organs of respiration, and (2) render the absorption of water more efficient and controllable in a water-logged soil, such as *D. ulliaceum* Bl. affects. The walls of the endoderm are not specially thickened; sooner or later they contain a suberised lamella.

Secretion cells occur in the cortex in all except the *Cedrela* spp.; but even in these their absence cannot be positively affirmed, as the material had lain in alcohol.

An endotrophic mycorrhiza, which appears to degenerate and to be digested in the deeper cortical cells, is present in more than half the species; in addition an exotrophic mycorrhiza occurs on some of the rootlets of *Sandoricum lucidum*.

In plants like the beech, which have thin much-branched rootlets, the total length of the rootlets and the total surface they utilise for absorption in a given volume of soil are greater than in plants like the ash, whose rootlets are thicker and less branched. The thin rootlets of the beech are in a better position to penetrate among the finer particles of the soil, and thus exhaust their water of hygroscopicity to the last drop. The beech is fitted for an intensive, the ash for an extensive, system of work.

The root system of Meliaceæ is fitted for extensive rather than intensive work. The rootlets are, relatively speaking, very thick and very scattered. The hairless rootlets of the *Dysoxylon* spp. in particular are strikingly thick, and recall those of a saprophytic plant.

The explanation of all appearances in the anatomy of the epiderm, hypoderm, and endoderm, and of the character of the root-system as a whole, whether intensive or extensive, must be sought for in the texture, composition, and continual or periodic dampness of the soil, in the leaf-arrangements for transpiration, and in the predisposition of the plant itself.

The work was carried out under the direction of Professor Büsgen in the Forstakademie, Münden, Hanover.

2. *The Structure and Wound-reactions of the Mesozoic Genus Brachyphyllum.* By Professor E. C. JEFFREY.

The affinities of *Brachyphyllum* have been much disputed since Brongniart first described it as a 'conifère douteuse.' From material with structure preserved by partial charring, from the Raritan deposits of Staten Island, N.Y., U.S.A., and representing the *Brachyphyllum macrocarpum* of Newberry, it has been possible to settle that the genus is an Araucarian Conifer of Cupressinoid habit. It differs superficially from any living representatives of the Araucarineæ by its flattened branches and adnate leaves. The central cylinder encloses a much smaller pith than do those of *Araucaria* and *Agathis*, and the pith is occupied by masses of sclerenchyma. The wood is of a more primitive type than that found in the still existing Araucarineæ, resembling the ancient Gymnosperms in the absence of wood parenchyma. The pits of the tracheids and of the rays are of the Araucarian type. The phloëm is without bast-fibres, and resembles in this respect the Abietineæ. The leaf-traces pass off to the leaves with a well-marked foliar gap, and fork repeatedly in the leaves, as in *Agathis*, both features of difference from any known representatives of the Lycopods. No indications of the presence of ligular structures such as are found in some of the Lycopodineæ have been made out. The ramifications of the leaf traces become surrounded by transfusion tissue, resembling that found in many of the Abietineæ; for the phloëm is completely included by the tracheidal cells. The transfusional borders of the bundles fuse in the upper parts of the leaves, forming a continuous zone above the active parenchyma, which lies on the morphologically lower (outer) surface of the leaf, since the upper surface is adnate to the branch.

Araucarian cone-scales found in constant and intimate association with the branches described above and closely resembling those from Cretaceous deposits of Greenland, Europe, and the United States, referred by Heer and others to the living genus *Dammara*, are shown not to belong to this genus by the fact that they

bear not one but three ovules. They are considered to represent the cone-scales of the female cones of *Brachyphyllum*. These scales have been referred to a new genus, *Protodammara*. They possess a double system of bundles of opposite orientation and show no indication of the presence of anything comparable to a ligule. The lower series of bundles, corresponding probably to the fused sterile bract, which many authors accept as the morphological equivalent of the free bract which is found in the Abietinæ, are in their upper portions surrounded by zones of transfusion tissue which, like those in the leaves of *Brachyphyllum*, become confluent.

The wound-reactions of *Brachyphyllum* are strikingly similar to those of the Abietinæ, for in three different species of this genus from Staten Island, Martha's Vineyard, and the Potomac, it has been observed that traumatic resin-canals are the result of wounds, just as they are in *Abies*, &c. The occurrence of traumatic resin-canals is confined to *Brachyphyllum*, and is not found in other Cretaceous Araucarians, or in the living *Agathis* and *Araucaria*. This feature will be recognised by those who are familiar with the structure of coniferous woods as one of great importance.

Brachyphyllum, although undoubtedly Araucarian in its affinities, resembles the Abietinæ: (1) in the structure of its wood, (2) in the structure of the phloëm, (3) in the organisation of its leaf traces, (4) in the features presented by its wound-reactions. The cone-scales, which have been referred by Dr. Arthur Hollick and the writer to the new genus *Protodammara*, probably belong to *Brachyphyllum*, and represent a more reduced type of anatomical structure than that found in the Abietinæ. *Brachyphyllum* appears to remove the Araucarinæ from a position of isolation, and to show them as undoubtedly coniferous and allied to the Abietinæ.

3. *Zygosporé Germinations in the Mucorinæ.*¹

By A. F. BLAKESLEE, Ph.D.

The zygosporés of the Mucorinæ require a longer or shorter period of rest before they become capable of germination.

The germination of the zygosporés of the homothallic species *Sporodinia* is pure homothallic.

In the germination of the zygosporés of the heterothallic species *Mucor Mucedo*, the segregation of sex is completed at some time before the formation of sporangial spores, and all the spores in a given germ sporangium are of the same strain, either (+) or (-).

In the germination of the heterothallic species *Phycomyces nitens*, a segregation of sex may take place at the formation of spores in the germ sporangia, but is only partial. In addition to (+) and (-) heterothallic spores, spores are formed which give rise to homothallic mycelia characterised by a production of spirally coiled aërial outgrowths termed pseudophores and the occasional formation of homothallic zygosporés. A homothallic mycelium also may be obtained by bringing the germ tube to branch out to a mycelium before the formation of the germ sporangium.

The sexual character in these homothallic mycelia is unstable, and in their sporangia a segregation again takes place and (+), (-), and homothallic spores are produced.

The germination of the homothallic zygosporés is of the same type as that of the heterothallic zygosporés, and no fixation of the homothallic character takes place.

¹ *Annales Mycologiques*, vol. iv. No. 1, 1906. A Report as Research Assistant of the Carnegie Institution.

4. *Differentiation of Sex in Thallus, Gametophyte, and Sporophyte.*

By A. F. BLAKESLEE, Ph.D.

For the sake of discussion the germination of the zygospore of the Mucors may be compared with the germination of the zygote of higher forms. The germ tube of the Mucors would then be homologised with the sporophyte, and the mycelium with the gametophyte. To avoid the confusion occasioned by the terms 'monoecious' and 'dioecious,' which are indiscriminately applied to both generations, *homothallic* and *heterothallic* may be used in the gametophyte, and *homophytic* and *heterophytic* in the sporophyte, to distinguish more precisely the sexual condition in these stages.

All Phanerogams are heterothallic: *Lilium* may represent the homophytic, and *Populus* the heterophytic types.

In the *Pteridophytes*, *Polypodium* may represent the homothallic forms. The heterothallic forms may be represented by *Selaginella*, which is homophytic. No heterophytic species are known to exist.

Homo- and hetero-thallic forms occur among the Bryophytes, but up to the present time the sexual condition of their sporophyte has not been investigated. Evidence is at hand, however, which would indicate that the sporangium of *Marchantia polymorpha*, like the germ sporangium of *Phycomyces*, contains both male and female spores, and therefore this single species is to be classified as homophytic. Attempts are being made with regeneration experiments to determine at what point in the development of the sporangium the segregation of sex takes place.

The Mucorineæ, represented by *Sporodinia*, *Phycomyces*, and *Mucor Mucedo* respectively, constitute the only group in which the three possible types of germination from the zygote are known. With the exception of the Mucors, the sexual relations of the offspring from a single zygote in heterothallic Thallophytes such as *Edogonium*, the zygotes of which give rise to more than a single individual, have never been investigated.

5. *A Stigmaria of Unusual Type.* By Professor F. E. WEISS, D.Sc.

A *Stigmaria* of somewhat unusual type has been found in one of the nodules from the Halifax Hard Bed of the Lower Coal Measures. It differs from most specimens of *Stigmaria* in the considerable amount of primary wood which was centripetal in its development. In this character it resembles the *Stigmaria Brardi* described by Renault.¹ The centripetal development of the primary wood gives to the plant at first sight the appearance of a stem of *Lepidodendron*. But its stigmarian nature can be recognised by the absence of any hard outer cortex and by the characteristic periderm, to which are attached the remains of rootlet cushions. The vascular tissue supplying these rootlets has practically the same arrangement as that in *Stigmaria Brardi* of Autun, and the cortex has a considerable development of short reticulated tracheids, the function of which is still problematical.

6. *The Cross-Inoculation of Leguminosæ and other Root-Nodule bearing Plants.* By Professor W. B. BOTTOMLEY.

Nobbe, as a result of his researches, supposed that each leguminous plant required its own specific organism for nodule formation. Frank considered that each tribe of the Papilionaceæ had its specific organism. Beyerinck, whilst describing at least two distinct tribes of these organisms, says the failure to produce inoculation upon all legumes with one bacterium is a difference in variety rather than in species. Quite recently Dr. Moore, of the U.S. Department of Agriculture, has shown that it is possible to produce nodules upon practically all

¹ *Flore fossile d'Autun.*

the Papilionaceæ, provided the specific organism is first grown for two weeks upon a nitrogen-free medium. The present investigation was to test the possibility of cross-inoculation between the organisms found in the root nodules of the Mimoseæ (*Acacia*), Alder, and *Elæagnus* and various Papilionaceæ. The acacia nodules were obtained direct from the wattle scrub of Western Australia; the Alder and *Elæagnus* nodules from the Botanic Gardens, Regent's Park.

The nodules were sterilised first in weak hydrochloric acid, then in formalin. They were cut open under sterile conditions, and a small portion cut out from the centre and placed in 20 c.c. of a culture solution consisting of 1 per cent maltose, 0.1 per cent. potassium phosphate, and 0.02 per cent. magnesium sulphate. This was incubated for four days at a temperature of 25° C. Then 1 c.c. of this was used to inoculate a further 20 c.c. of the culture solution, to which had been added 0.5 per cent. ammonium phosphate. After inoculation for two days the solution became turbid, and was then used for the inoculation experiments.

Seeds of sweet-peas and tares were planted in pots containing sterilised sand, and watered with a nitrogen-free nutrient solution. After germination one set of pots was inoculated with dilute culture solution, a second set remaining untreated as a control. At the end of four weeks' growth the plants were examined, when it was found that every plant in the inoculated set possessed nodules, whilst not a single nodule was found on the uninoculated plants.

7. *Nitrifying Bacteria in the Velamen of certain Orchids.*

By Professor W. B. BOTTOMLEY.

It has long been known amongst orchid growers that sprinkling urine on the floor of the greenhouse caused a more luxuriant growth of the plants. The ammonia liberated by the decomposition of the urine is absorbed along with the aqueous vapour condensed by the velamen cells, but exactly how the absorbed ammonia was utilised by the plant was not known.

The result of the present investigation has been to show the presence of both nitrite and nitrate bacteria in the velamen cells.

The nutrient fluids used were those recommended by Winogradsky: 1 gm. potassium phosphate, 0.5 gm. magnesium phosphate, 0.5 gm. basic magnesium carbonate in 1,000 gm. distilled water. To this solution is added 0.2 gm. ammonium sulphate for the nitrite bacteria, and 0.2 gm. potassium nitrite for the nitrate bacteria.

Test tubes containing 30 c.c. of the culture solution were inoculated with the velamen cells from *Cattleya*, *Dendrobium*, *Oncidium*, and *Angræcum*, with a control tube in each case.

The tests used were sulphanilic acid and naphthylamine hydrochloride for nitrites, and phenol-sulphonic acid for nitrates. In every case the tests showed the presence of nitrites and nitrates respectively in the inoculated tubes.

Growth of the organisms was very slow. After seven days there was only a faint trace of oxidation, but after a month it was very evident.

8. *On the Taxonomic Value of Cilia in Bacteriology.* By DAVID ELLIS.

The latest classification of Bacteria—viz., that of Migula—uses the presence or absence of cilia as a diagnostic of ordinal value. The Coccaceæ are divided as follows:—

- | | |
|------------------------|---|
| 1. Streptococcus . . . | Dividing in one direction of space, and therefore producing chains of cocci. |
| 2. Micrococcus . . . | } Dividing in two directions of space, and therefore producing plates of cells. |
| 3. Planococcus . . . | |
| 4. Sarcina . . . | } Dividing in three directions of space, and therefore producing packages of cells. |
| 5. Planosarcina . . . | |

1, 2, and 4 are further distinguished by a want of motility; 3 and 5 by its

presence. By appropriate treatment 1, 2, and 4 can all be rendered motile, hence *all* the Coccaceæ are motile.

The next division—Bacteriaceæ—is divided as follows:—

1. Bacterium . . . Non-motile.
2. Bacillus . . . Motile, cilia all round.
3. Pseudomonas . . . Motile, cilia polar.

By the same treatment the forms classified as Bacterium can be made motile, so that the whole of this group has motile forms, and the distinction between Bacterium and Bacillus is non-existent.

The third division—Spirillaceæ—is divided as follows:—

1. Spirosoma . . . No organs of motion.
2. Microspira . . . 2-3 polar cilia.
3. Spirillum . . . 5-20 polar cilia.
4. Spirochæte . . . Cells without organs of motion, but possessing a wavy motion.

Spirillum has often a larger number of cilia than twenty. On the result of the above investigations there can be little doubt that the genera Spirosoma and Microspira will have to be merged into the genus Spirillum.

We can therefore affirm that motility, either potential or actual, is a characteristic of all the forms of the three divisions—Coccaceæ, Bacteriaceæ, and Spirillaceæ.

MONDAY, AUGUST 6.

Joint Discussion with Section D on Fertilisation.

The following Papers were read:—

1. *The Nature of Fertilisation.* By VERNON H. BLACKMAN.

An attempt is here made to give a brief account of some of the recent work on which the more modern views of the nature of fertilisation are based. The term fertilisation is used in its widest sense, to include any gametic union of cells and nuclei, and is thus equivalent to the *syngamy* of Hartog.

In the cytological life-history of the higher organisms which reproduce themselves sexually three main cytological stages are to be observed—a stage of cell and nuclear union, a stage of somatic divisions, and a stage of reduction which halves the number of chromosomes. The advantages of gametic union have been supposed to be rejuvenescence and the union of two lines of descent. The rejuvenescence theory is supported by the observations of Maupas and of Calkins on Protozoa, but both views are difficult to apply generally, in view of the groups which show no gametic unions, and the large number of organisms, especially plants, in which the fusing cells or nuclei are very closely related.

In view of the general constancy in the number of chromosomes, reduction is a necessary corollary to fertilisation; and since Van Beneden in 1883 showed that in *Ascaris* the number of chromosomes in the sexual cells was only half the number normal for the somatic cells, various theories have been put forward as to the method by which reduction is brought about. The reduction has been shown to take place at a definite point in the life-cycle (at least in the higher animals and plants), to be associated with a peculiar condensation of the chromatin of the nucleus (synapsis), and with a tetrad division of the mother-cells concerned. The general theory of the individuality, or, rather, autonomy, of the chromosomes has gained ground, and attention has been focussed on the question of the nature of the reduction process in connection with the rediscovery of Mendelian inheritance. The most important

step in advance as to the nature of reduction was made by Montgomery, in 1901, when he put forward the theory, now generally accepted, that in synapsis *maternal and paternal chromosomes unite in pairs*, and are later separated by the reduction division, which thus divides the somatic chromosomes into two groups. In the life-cycle of the organism we have thus: Conjugation of maternal and paternal cells, somatic divisions, and conjugation of maternal and paternal chromosomes. The later observations of Montgomery and those of Sutton, McClung, Boveri, Baumgartner, Wilson, &c., on the difference in size, in form, and in physiological function of the chromosomes, all point to the probability that the somatic nuclei contain two parallel series of chromosomes, derived respectively from the maternal and the paternal sides; and that in synapsis there is a conjugation of 'homologous' chromosomes, which are later separated in the reduction division. The exact mode of conjugation of the chromosomes is disputed, but observers are generally agreed as to the end result—the separation of whole somatic chromosomes. The interest of this view is that it is in general agreement with Mendelian results, if we assume that the hereditary characters are distributed among different chromosomes. A point of great interest is what interaction, if any, takes place between the chromosomes during conjugation, but for an answer to this question only the indirect evidence of heredity is available. There is another difficulty: if unit characters are sorted out by means of the separation of whole chromosomes, then, in such a form as that of *Ascaris*, with only two chromosomes in its somatic cells, mixing of characters would be impossible, except in the individual concerned, for maternal and paternal characters would be completely separated during reduction; also, in such forms as *Canna*, which have only a small number of chromosomes, there should be an extraordinarily high degree of correlation in the sorting of the unit characters.

The process of fertilisation, though sharply characterised in its higher manifestations, seems almost incapable of exact definition either physiologically or morphologically, for such reduced conditions as 'apogamy' and 'parthenogenesis' link it on to vegetative reproduction. Nuclear fusions and reductions appear to occur in plants apart from reproduction, and in some graft-hybrids there is evidence that the fusing of vegetative cells has led to the mixing of characters.

2. *The Protozoan Life-Cycle.* By G. N. CALKINS.—See p. 596.

3. *The Maturation of Parthenogenetic Eggs.* By L. DONCASTER, M.A.

The first systematic work on the maturation of parthenogenetic eggs was that of Weismann and Ischikawa (1888). In a number of Entomostraca and Rotifers they found that parthenogenetic eggs produce one polar body, fertilisable eggs two, and they regarded this as being probably a general rule. It was soon discovered, however, that eggs which produce two polar bodies may develop parthenogenetically. Plattner (1888) found this in the moth *Liparis dispar*, the eggs of which may develop although not fertilised; and Blochmann (1889) showed that two maturation divisions take place in the Bee's egg, whether fertilised or not. This has been confirmed by Petrunkevitch (1901). In these cases the egg may be fertilised, but develops whether spermatozoa are present or not. Henking (1902) found that in the gall-fly *Rhodites* there are two maturation divisions, and in this case the egg is rarely if ever fertilised, males being extremely rare. Since then the same thing has been found in Sawflies, in which there are always two maturation divisions; and in some species virgin eggs yield males, in others females; in some of the latter males are unknown. Henking believed that in *Rhodites* there was no reduction in Weismann's sense, and the same is probably true at least of the female-producing Sawflies; but according to Petrunkevitch the chromosome number is reduced in the Bee, and when the egg is not fertilised it is automatically restored to the somatic number. Very little is as yet known on this subject; it is almost certain that when there is only one maturation

division, as in the cases examined by Weismann, there is no reduction; and this has been shown to be true also in *Aphis* by Miss Stevens (1905); but it seems that where two maturation divisions take place in parthenogenetic species there may be either a reduction or two equational divisions in different cases. It is also possible that both methods may occur in different eggs of the same species.

In 1897 Erlanger and Lauterborn discovered that in the rotifer *Asplanchna* the parthenogenetic eggs which yield females produce only one polar body, while those giving rise to males produce two. In the bee and some other animals, where there are two maturation divisions, males only are produced from virgin eggs, and Castle (1903) used this fact in formulating his ingenious hypothesis of the segregation of sex-determinants in a way analogous to the Mendelian segregation of inherited characters. But since his paper was published, several exceptions have been discovered, the most important of which is *Aphis*, in which parthenogenetic eggs yielding both males and females have only one polar body. This has also been found by Morgan in *Phylloxera* (1906).

The fate of the polar nuclei in parthenogenetic eggs seems to vary greatly in different species. In some the polar bodies are thrown out of the egg and lost; in others the nuclei remain in the egg, and in that case the first polar nucleus divides at the time when the second is separated from the egg-nucleus. Frequently the two inner polar nuclei, or, in other cases, all three, fuse together and give rise to a group of chromosomes which generally ultimately disintegrate; but, according to Petrunkevitch, in the bee the two inner nuclei fuse and give rise to a group of nuclei which ultimately form the testis of the drone; and Silvestri in *Litomastix* (a parasitic hymenopteran) says that the polar nuclei proliferate and form a layer which gives rise to the membrane enclosing the embryo. In *Artemia* Brauer found two types of maturation; most commonly only one polar body was formed, and the egg-nucleus contained the reduced number of chromosomes, each of which was double. But more rarely two polar nuclei are produced, and in this case the inner sinks back into the egg and conjugates with the egg-nucleus, taking the place of the spermatozoon. An exactly similar process has been described (1904) by Brues in a parasitic insect (Stylopidae).

The question as to whether the somatic number of chromosomes can be restored if the egg begins to develop with the reduced number has given rise to much controversy. In the bee, according to Petrunkevitch, the reduced number is eight, but he found sixteen in the first mitosis of the egg-nucleus. In the blastoderm divisions, however, he found sixty-four, so that the chromosomes in the maturation divisions must be regarded as compound, and the increase in number loses some of its significance. So, also, Henking found in *Rhodites* that the number increases from nine to eighteen; but he also supposes that in the polar mitoses they are bivalent. In some, at least, of the sawflies the number seems to remain constant, and there is probably no reduction during maturation.

In the case of eggs made to develop parthenogenetically by artificial treatment there is no better agreement. According to Wilson and Boveri in sea-urchins the chromosomes remain at the reduced number; but Delage states that the number is automatically doubled and the nucleus restored to the somatic condition. Kostanecki (1904) has attempted to explain this divergence by observations made on *Maetra*. When the eggs are caused to develop artificially, a spindle is formed, giving rise to two nuclei lying side by side; but at the next division a single equatorial plate is formed by the two nuclei containing the somatic number of chromosomes, and this number is maintained in the subsequent divisions. Petrunkevitch has also investigated artificial parthenogenesis, and finds that the chromosome number varies, owing to splitting sometimes taking place without nuclear division and owing to multipolar mitoses. It appears, therefore, that there is no regularity, and probably in some cases the reduced number is maintained; in others the somatic condition may be restored by abnormal divisions.

4. *Formation of the True Nucleoli or Plasmosomes of the Somatic Cells: A Contribution to the Study of the Formation of the Plasmosomes in the Nerve and Blood Cells of some Batrachians, viz., Rana temporaria and Alytes obstetricans.* By Professor T. HAVET.

The plasmosome of somatic cells is usually circular in shape and situated within the nucleus. It consists of a central part which stains with acid dyes (acid fuchsine, eosin, Congo red, orange, &c.), and a peripheral granular portion coloured by basic stains; ex. hæmatoxylin.

Nothing is known as to the formation or origin of the plasmosome, except that it makes its appearance during the telophase and disappears at the prophase.

In my researches regarding the origin of the true nucleoli I have carefully observed all the details of the different phases in their formation in the nerve, blood, and connective-tissue cells of the tadpoles of frogs and toads, and have obtained the following results. The true nucleolus makes its appearance at the very commencement of the telophase as a small clear area, which does not take the colouring reagents. It lies in the centre of the telophasic figure, and can only be seen when this figure is viewed from its summit. The chromosomes thus examined are found to be piled up against one another (the polar aspect) and arranged radially around the central clear area. The chromosomes then become vacuolated and form themselves into a network, which first appears in the external portion of the telophasic figure, while the internal portion of the latter (*i.e.*, that in proximity to the clear central zone) remains thickened. Gradually the alveolisation and network formation extend inwards towards, but not reaching quite up to, the central area. The internal extremities of the chromosomes do not become vacuolated, but persist as a circle of granulations or chromatic blocks around the clear central area. This area has in the meanwhile become slightly enlarged, owing probably to the enchylematic fluid, which at this period is found in abundance.

The study of the formation and origin of these plasmosomes furnishes a good indication of their structure. The central plasmatic portion, coloured by the acid dyes, being constituted of a more or less modified nuclear enchylema, while the peripheral basic staining portion is derived from the internal extremities of the concentrated, non-vacuolated chromosomes.

It should be remarked that the central portion often contains a kind of network, formed by a chromatic substance of nuclear nature and staining with hæmatoxylin, the peripheral zone having the same structure and origin as described above.

Whence arises this special structure? It sometimes happens that a chromosome, instead of behaving like the others equidistant from the central zone, becomes included and traverses this central area, where it also undergoes vacuolation, thus giving rise to the chromatic reticulation in the central area of the plasmosome.

When, from some unknown cause, the chromosomes unite during the telophase into several (usually into two) bundles, their behaviour is the same, except that they are arranged around two (or more) clear areas instead of one; hence the explanation of the occurrence of several plasmosomes within a single nucleus. I have frequently noticed the presence of two such bodies.

It is well known that at the prophase—that is to say, at the moment of the recondensation of the chromatin and of the reconstitution of the chromosomes—the nucleolus disappears. The peripheral zone of the plasmosome is derived from a portion of the chromosomes, as is also the remnant of the chromatic network, and both furnish material for the reconstitution of the chromosomes. The central part of the plasmosome, which is merely nuclear enchylema more or less modified, becomes mingled with the surrounding nuclear enchylema. Hence the explanation of the disappearance of the nucleoli, which has been the object of my study.

It is easily understood what happens at the prophase in the case of the plasmosome having a chromatic network within its central zone.

5. *Some Impressions of South African Vegetation.*
By Professor R. H. YAPP, M.A.

6. *Algal Ecology and Biology.* By Miss FLORENCE RICH.

Periodical observations are being made, in conjunction with Dr. F. E. Fritsch, on the algal vegetation of ponds, in the hope that by this means light may be thrown on problems of algal ecology and biology that have hitherto received but scant attention. From certain ponds monthly samples have been taken, from others fortnightly ones. These exhibit marked periodical variations.

Great differences have also been observed in the algal vegetation of neighbouring ponds. Certain algæ appear to be commonly associated with one another; it may be possible after a time to classify waters according to the types they contain. There may also be a connection between the algæ and the aquatic Phanerogams present. Determinations of the external conditions to which any given piece of water is subjected, such as average temperature, average illumination, variations in shading and exposure, nature of drainage received, and so on, must ultimately lead to recognition of the dominant factors to which different kinds of algal growth are due. The combination of conditions influencing the reproduction of one particular species in different ponds will, it is hoped, gradually be made out, and then the probable factors affecting reproduction may be recognised, though the results will still want testing by experimental methods in the laboratory.

7. *The Algal Vegetation of Ponds.* By NORMAN WALKER.

The ponds examined are situated above the Bramhope railway tunnel, near Leeds, and occupy excavations in clay which were made sixty-seven years ago. An abundant flowering-plant vegetation which has established itself encourages mud formation and renders the ponds favourable to a rich algal vegetation. The following are the available sites for attached algæ:—

SITE 1.—Winter shoots of *Enanthe fistulosa*. These form a pale green zone, from 2 to 3 yards wide, extending from the edge of the pond to a depth of about 9 inches. In winter this site is brightly illuminated and the water is thoroughly aerated by surface movements, caused by wind. During the course of the year a succession of algal associations occurs here. The factors controlling this distribution are, probably, changes in temperature with accompanying variation in dissolved gas content, and interference of light by the Plankton, chiefly *Peridinium tabulatum*.

September to May.—*Tribonema bombycinum* (Ag.) Derb. and Sol., dominates, with abundant *Ulothrix subtilis* var. *variabilis*, Kutz.

June.—*Tribonema* and *Ulothrix* disappear and *Zygnema* spp. (sterile) is established, which in turn is followed by *Tolypothrix lanata* (Desv.) Wartm.

July and August.—(With increasing temperature of water, accompanied by rapid decomposition of vegetable matter) *Anabaena oscillarioides*, Bory, followed by *Oscillatoria anguina*, Bory, with *Phormidium molle* (Kutz.) Gom. These are displaced by *Oscillatoria amphibia* Ag., and finally, in small warm pools, where decay is very rapid, *Beggiatoa alba* and *Cladothrix dichotoma* are found upon the remains of the foregoing plants.

SITE 2.—Shoots of *Potamogeton natans* and *Sparganium ramosum* occurring in the deeper water (1 to 3 feet). In winter the old decaying shoots of these plants afford a considerable surface at various depths and degrees of illumination for the attachment of numerous epiphytic forms. The vertical distribution of these algæ is in some cases striking, and seems to be affected by surface commotion caused by wind and by differences in the illumination.

Winter.—Species of *Edogonium* and *Bulbochæta* dominate.

Spring.—*Spirogyra Weberi*, Kutz, and other filamentous conjugatæ.

Summer.—Species of *Mougeotia* with desmids.

In one shallow pond with deep mud *Spirogyra longata* (Vauch.) Kutz. dominates throughout the year, but in the hotter months of 1905 this was invaded by *Microcystis roseo-persicinus*, Kutz. which formed a striking pink 'water blossom.' *Phormidium inundatum*, Kutz., also occurred as a covering upon the mud. During hot sunny days this alga rises to the surface, and there becomes disposed in a thin layer. This ascent to the surface is due to the motility of the filaments, and takes place along threads of *Spirogyra*, which often form the core of the ascending column. This power of movement is of great importance to species of *Oscillatoria* and *Phormidium*, and enables them to migrate from a situation of extreme stagnation to the better aerated surface region.

SITE 3.—Short decaying shoots of the smaller flowering plants, such as *Carex vulgaris* and *Eleocharis palustris*, which cover the floor of the pond in the shallower parts not occupied by *Cenanthe*. Dipterous insect larvæ, nais and nematoid worms, abound here and influence the algal vegetation. The dominant alga is *Glaucocystis vesiculosa*, Nag. Many other small gelatinous forms flourish in this situation.

TUESDAY, AUGUST 7.

The following Papers were read:—

1. *On the Seedling Structure of Gymnosperms.*
By T. G. HILL and E. DE FRAINE.

Taxus baccata.—The two cotyledons each contain a single collateral bundle, which is, in some cases, slightly mesarch. A section of the axis, taken through the cotyledonary node, shows the central region to be occupied by six plumular bundles arranged in two groups. Each seed-leaf trace, at its entry into the hypocotyl, has its xylem arranged in a V-like manner, the protoxylem being near the apex, which is pointed outwards. Each cotyledonary bundle travels obliquely downwards, and during its passage the phloëm is resolved into two parts. At the same time the metaxylem passes in more quickly than the protoxylem, so that the latter, for a time, is entirely mesarch in position. The phloëm masses of the cotyledon bundle fuse with the corresponding tissue of the nearest plumular bundle—the three strands of each group having fused together—and, concurrently, the metaxylem of the same traces moves towards the xylem of the epicotyledonary bundles; hence the protoxylems of the seed-leaves are left in a more exarch position, and, ultimately, are quite exposed. The vascular tissues close up and become more compact, thus a typical diarch root results. It is not possible to distinguish any rotation of the protoxylem: it ultimately occupies an exarch position, because it is left isolated by the movements of the metaxylem. There may be made out, however, an indefinite rearrangement of the protoxylem, coupled with a slight centrifugal movement, after the exarch position has been attained.

Taxus cuspidata, as far as can be ascertained from the study of old seedlings, does not differ in any essential feature from the above species.

Cephalotaxus pedunculata is very similar to *Taxus*. The main points of difference are as follows: (a) The single bundle of each cotyledon shows the mesarch structure more highly developed; and (b) the seed-leaf traces do not bifurcate so soon. They enter the central region of the axis as well-defined collateral endarch structures, and form a cylinder with the plumular traces, the phloëm forming a practically closed ring. At a lower level, the bast-circle divides, opposite the cotyledon bundles, into two well-defined masses. During this rearrangement the xylem groups come into contact, the metaxylem derived from the seed-leaves joins up with the plumular xylem, and thus the protoxylem becomes isolated. The subsequent changes are essentially the same as those described for *Taxus*.

Cupressus pisifera, *C. Lawsoniana*, and *Thuja orientalis* all have two cotyledons, each with a single collateral vascular bundle. The transition phenomena are of the same type as in *Taxus*, and result in the formation of a diarch root.

Libocedrus decurrens, also, is similar, but the number of seed-leaves is three, and the primary root is triarch.

Cedrus Deodara.—There are usually eleven or twelve cotyledons; the number, however, varies. Each contains a single collateral endarch bundle throughout its whole length.

Above the cotyledonary node the seed-leaves fuse to form a well-defined tube, the inner surface of which is corrugated; each ridge corresponds to a cotyledon, the foliage leaves of the first node fit into the furrows, and, before the axis is reached, these leaves fuse with the cotyledonary tube. Fusion with the axis takes place, and the general appearance of a transverse section, taken immediately below the cotyledonary node, is that of a monocotyledonous stem. This appearance is, of course, due to the disposition of the leaf-traces of the first three or four nodes; these bundles, however, speedily lose their identity, and, a little later, so also do the vascular strands of the first node. The bundles of the cotyledons now become placed closely together, so that the limits of any one is difficult to determine. At a lower level a gradual change occurs; the phloëm groups fuse together in pairs, and at the same time the masses of xylem undergo rotation in such a manner that two neighbouring protoxylems become exarch, fuse, and occupy positions alternating with those taken up by the phloëm groups. Thus a typical root is formed, usually pentarch or tetrarch.

Pinus Murrayana var. *Sargentii*.—Four cotyledons are usually present: each contains a single bundle which has transfusion tracheïdes adjoining.

Near the base of the cotyledons the phloëm of the bundles bifurcates, and the xylem rotates in such a manner that the protoxylem becomes situated between the two groups of phloëm elements. In this condition they enter the axis, and in their passage towards the centre the rearrangement becomes more marked. During the downward course the eight phloëm groups fuse in pairs, the metaxylem takes up a position internal to the phloëm, and, as the protoxylem is already exarch, a tetrarch root is formed.

There is, however, some variation. Thus another seedling also had four cotyledons, the bundles of three of which exhibited the rearrangement described above while still in the leaf, while the fourth remained undivided throughout its whole course. The central region of the axis being reached, the fourth cotyledonary bundle played the part of a plumular trace, and fused up with the two epicotyledonary bundles situated upon its flanks. The other three seed-leaf strands behaved in the manner already indicated above. Their phloëm groups joined with the adjacent bast of the plumular bundles, and the same applies to their metaxylem elements. A triarch root was thus formed.

Pinus montana var. *gallica*, *P. sylvestris*, *P. Thunbergii*, *P. Gerardiana*, and others all follow a course similar to the above. There is, however, much variation both in the number of the seed-leaves and also in the behaviour of the bundles of the cotyledons.

Tsuga diversifolia may be placed in a position intermediate between the *Taxus* and *Pinus* types.

2. On the Seedling Structure of certain Centrospermeæ. By T. G. HILL.

NYCTAGINACEÆ:

Allionia albida, Walt.—The petiole of each cotyledon contains a central strand, consisting only of a very few tracheæ, derived from one of the bundles of the midrib, and bounded on each side by two normal collateral bundles, the smaller ones being outermost. Near the base of the petiole the traces *a* fuse with the larger bundles *b*. The axis, at the level of the cotyledonary node, contains six plumular strands, which soon fuse together to form two. On the arrival of the seed-leaf bundles into the central cylinder, the groups of tracheæ *c* 1 and *c* 2 occupy their isolated

positions between the bundles b 1, b 2, and b 3, b 4 respectively; while b 2, b 4, and b 1, b 3 are separated by the plumular traces d 2 and d 1 respectively.

Following the hypocotyl downwards, the relations between the bundles are somewhat complicated. c 1 and c 2 occupy their position throughout, but there is much anastomosing between the bundles of the series b and d . At the same time the protoxylems of b 2, b 4, and b 1, b 3 rotate towards d 2 and d 1 respectively. This rotation is, however, vacillating, and the rearrangement arrived at may be obliterated by the formation of a branch passing from b 3 to d 1, for example. Finally, however, the branching stops, the strands d 1 and d 2 having combined with one of the bundles situated on their flanks, and a definite rotation of the protoxylems b 2, b 4, and b 1, b 3 takes place. The condition now obtaining is that of a tetrach root; this last movement, however, is too late, for almost immediately the phloëm and metaxylem of b 2, b 4, and b 1, b 3 fuse together, enclosing in their meshes the exarch protoxylem which was derived from these same bundles. Thus the groups of tracheids c 1 and c 2, which have been gradually increasing in number, form the protoxylem of the diarch root.

Mirabilis divaricata, Lowe, follows a similar course.

AMARANTACEÆ:

Amaranthus hypochondriacus, L.—Each cotyledon has a single bundle. Bifurcation of the phloëm and the rotation of the xylem towards the exarch position commences some way up the petiole. On the central region of the axis being reached, the rotation of the xylem is seen to be complete, the metaxylem elements speedily pass inwards and, at a lower level, the opposing masses of phloëm fuse together. A diarch root is thus formed.

The same changes occur in *A. caudatus*, L.

The transition-phenomena in all the following plants are essentially of the same nature as in *Amaranthus*:—

AIZOACEÆ:

Tetragonia expansa, Murr., *Mesembryanthemum crystallinum*, L.

CARYOPHYLLACEÆ:

Corrigiola litoralis, L., *Lychnis Viscaria*, L., *Polycarpon tetraphyllum*, L., *Silene Otites*, Sm., and *Silene pendula*, L.

PORTULACACEÆ:

Portulaca oleracea, L., *Calandrinia Menziesii*, Torr. et Gray.

CHENOPODIACEÆ:

Atriplex hastata, L., *Chenopodium Bonus-Henricus*, L., *Spinachia oleracea*, L.

3. *The Phylogenetic Value of the Vascular Structure of Spermophytic Hypocotyls.* By A. G. TANSLEY and E. N. THOMAS.

The subject of this communication has been under investigation for several years past. Owing to the vastness of its extent the territory is still very incompletely explored, but enough data have been brought to light to warrant a preliminary setting forth of some results.

The success of Jeffrey, Gwynne-Vaughan, Boodle, and others in elucidating the phylogeny of the vascular system of Ferns by a study of its ontogeny naturally suggests a parallel investigation among flowering plants; but here we are met by a different type of early ontogeny depending on the habit of intra-seminal embryo formation, and involving the appearance of the *hypocotyl*, an organ whose nature and origin are still the subject of dispute. Whether we regard the hypocotyl as the equivalent of the first portion of the stem of a Pteridophyte, or as a new organ developed subsequently to the evolution of the seed-habit, we clearly have to face

a break in the history of development of the stem, which masks, if it does not destroy, the succession of phases of vascular evolution met with in Ferns.

Nevertheless the hypocotyl itself, with its direct continuation downwards—the primary root—and its appendicular organs—the cotyledons—may be considered apart from questions as to its origin, so that it remains to determine whether its characters, such as the anatomical features of its vascular system, have phylogenetic value; and if so, what are the actual plans of structure met with, and the phases of evolution through which they pass.

Miss Sargent's work¹ has established the phylogenetic value of the vascular symmetry of the hypocotyl in certain Monocotyledons, particularly Liliaceæ, and our results for Gymnosperms and Dicotyledons confirm and extend her conclusion.

The different types of 'transition' between the collateral structure of the vascular tissue of the cotyledons and the radial structure of the primary root-cylinder we find to be all, with a very few exceptions, modifications of one great plan. The primary root is, in the vast majority of cases, either diarch or tetrarch, and the plane passing through the centres of the two cotyledons (cotyledonary plane) also passes through the protoxylem poles of the diarch root, or through two out of the four poles of the tetrarch root. This was established by Dangeard² in 1889.

The characteristic dicotyledonous type has, near the base of each cotyledon-petiole, a striking type of bundle—the 'double bundle'—very variable in details, but characteristically consisting of a V-shaped strand with two phloëm groups on the arms of the V, and the xylem occupying the apex. Frequently this bundle is exarch, *i.e.*, the protoxylem is turned outwards between the phloëms. At or shortly below the cotyledonary node the xylems of the two cotyledonary double bundles become exarch, if they are not so already, and fuse to form the diarch plate; while of the four phloëms two join on each side of this plate to form the two phloëm strands of the root-cylinder. This type is found, not only in the Ranunculaceæ and several allied families and throughout the Rhæadales, but also in many other families of Archichlamydeæ, and is apparently typical of the Symptelææ.

In addition to the 'double bundle' two laterals exist in many cotyledon-petioles. Often they join on to and lose themselves in the double bundle towards the base of the petiole, but in other cases they may persist into the node and each take up a position, close to the corresponding one from the other cotyledon, in the intercotyledonary plane. Their xylems may either eventually lose themselves in the sides of the diarch plate, the protoxylems dying out (*Liriodendron*, *Cycas Siamensis*), or they may form the intercotyledonary poles of a tetrarch root (*Casuarina*, *Althæa*, *Ceratonia*, &c.).

In other cases, again, in which a tetrarch root is formed, we have exactly the same state of things as that just described, except that the double bundle is represented in the cotyledon-petiole by two distinct and separate collateral bundles (making, with the laterals, four in all), which eventually rotate, with their xylems inwards, so that their protoxylems come together to form the cotyledonary pole of the root-cylinder (*Ricinus*, *Cucurbita*, *Acer*, &c.).

It is plain that the cases described are naturally regarded as stages in a series.

The evidence points, we think, to the last case described being phylogenetically the oldest type, since it is typical (so far as we have been able to extend our researches) of Cycads and of Araucariææ. It has been retained, we think, in certain dicotyledons, though the transition from the shoot-type to the root-type of vascular arrangement has often been shifted right down to the base of the hypocotyl or even into the primary root. Most of the Coniferæ and the vast majority of Dicotyledons investigated by us have, however, undergone, according to our view, a reduction, first by the fusion of the two central cotyledonary bundles to form the 'double bundle,' the tetrarch type of root being here retained, and eventually by the disappearance

¹ 'A Theory of the Origin of Monocotyledons based upon the Structure of their Seedlings,' *Ann. of Bot.*, 1903.

² Dangeard, 'Recherches sur le mode d'union de la tige et de la racine chez les Dicotylédones,' *Le Botaniste*, 1889.

of the laterals leading to the typical dicotyledonous structure with a diarch root first described.

The evidence for this view of progressive reduction is primarily the prevalence of the more complex types in the older Gymnosperms, but other considerations that can be adduced in its support cannot be given in an abstract. The difference between the more complex and the simpler types cannot be directly correlated with habit, as might perhaps be thought; since there are instances of the same type occurring in allied species of totally different seedling-habit. The suggestion is made that the reduction has been brought about by such factors as reduction in the size of the seed, leading to the formation of a much smaller seedling with smaller and shorter-lived cotyledons, in which the plumule develops soon and rapidly, and the cambium becomes active in the hypocotyl and root at a very early period.

The level at which transition from endarchy to exarchy takes place is very variable. It seems that a high transition, typical of Gymnosperms and very many Dicotyledons, is probably primitive. The continuation downwards through the hypocotyl of separate endarch collateral bundles of the cotyledon traces in a relatively peripheral position, *i.e.*, stem structure of the hypocotyl, has apparently been acquired in a number of cases in which the hypocotyl projects considerably above the ground, and early has to support a weight of foliage.

4. *The Seedlings of certain Pseudo-Monocotyledons.*

By A. W. HILL, M.A.

The majority of the dicotyledonous plants which are bulbous or geophilous in habit possess some peculiarity in their method of germination, which is most commonly of a monocotyledonous character.

Certain bulbous and rhizomatous species of the genus *Peperomia* from the mountains of South and Central America have pseudo-monocotyledonous seedlings. They are, however, really dicotyledonous, but the behaviour of the cotyledons is dissimilar. In the early stages of germination they both serve as absorbent organs; very soon one of them grows quickly and is withdrawn from the seed to serve as an expanded assimilating organ, whilst the other remains within the seed and never emerges, but serves to absorb the reserves stored in the perisperm. In appearance the seedlings are monocotyledonous, and their method of germination appears to be unique. This case suggests that evolution along similar lines may have produced the normal seedling habit of such monocotyledonous orders as the *Araceæ*, &c.; for it is possible that the absorbent cotyledon and the so-called 'first-leaf' may stand in the same relation to each other and be equivalent to the two cotyledons of *Peperomia*. Some support is given to this view by the fact that the cotyledon and first-leaf are directly opposite to each other in the *Araceæ*.

In the case of the genus *Cyclamen* there are some differences. Here the embryo is truly dicotyledonous, but normally only one of the cotyledons is developed, and after serving as an absorbent organ it expands and becomes an assimilating organ. The rudiment of the other cotyledon is always present and visible, and it will usually develop into a normal green leaf should anything untoward happen to the first cotyledon. In some species of this genus the second cotyledon is found to resemble closely the first cotyledon, whilst in other species it more nearly resembles the ordinary foliage leaves. Some light may be thrown on the origin of certain monocotyledons from a consideration of these anomalous dicotyledons. It may be possible that the monocotyledonous mode of germination has been evolved owing to the assumption of different functions by the two cotyledons, in correlation with the adoption of the bulbous habit owing to adaptation to xerophytic conditions.

SECTION L.—EDUCATIONAL SCIENCE.

PRESIDENT OF THE SECTION—Professor M. E. SADLER, M.A., LL.D.

THURSDAY, AUGUST 2.

The President delivered the following Address:—

THE Committee of this Section, feeling that in England we are at the opening of a new chapter in our educational history, have endeavoured to arrange a programme which, so far as the limits of time allow, will enable members to discuss the chief aspects of the many-sided problem of school reform. Some sides of this question, political and ecclesiastical rather than educational in character, are by the rules of the Association rightly excluded from debate as being unsuitable for discussion in such an assembly as this. But plenty has been said about these topics elsewhere, and there remains for us a series of questions not less pertinent to the main issue, and scientific in their range without being politically controversial. With your leave, therefore, but with a strong sense of the difficulty of the task and of the greater fitness of several other members happily present among us to undertake it, I will attempt in this address to say something by way of general introduction to the debates which lie before us during the next few days.

During the last ten years more thought and labour have been given to educational questions in England than at any earlier period in our history. If we compare the present state of things with that of a decade ago, we have good reason for encouragement and hope. Great additions have been made to the number of our schools and universities; great changes have been made in the machinery of educational administration, and an even greater change has come over the attitude of mind in which thinking people approach the question of what our schools should teach, how they should teach it, and what should be the social purpose underlying, directing, and inspiring their work. We have moved, often unconsciously, from our old moorings. A strong current which we could not resist has shifted us from where we lay, more or less comfortably, before. And we have had to move in a fog, a puzzling and dangerous fog, now impenetrably thick and now lifting enough to show that we are still moving fast into unfamiliar waters. First on one side and then on another we have heard angry cries at impending collision. But the current carries us on amid conflicting advice as to the handling of the boat and much discord of opinion as to whither we are really going.

If, however, we review the general course of events in English education during the last few years, certain changes stand out conspicuously and call for special notice. There has been a great growth in public control over educational work. The chief tendency of recent legislation has been to strengthen the powers of the Board of Education on the one hand and of the local authorities on the other. It is true that many of these powers have not yet been fully exercised, but they have been granted, often without serious challenge, and they lie in

reserve. Whether in course of time the enforcement of these powers will come chiefly through the central authority or through the local authorities is still uncertain. The cantonal principle and the national principle are struggling for the mastery. Probably neither of them will completely prevail. But considerations of finance, the growing need for increased contributions from the Treasury in relief of local rates, and the accumulation of experience in the very large and widely distributed staff of the central authority, point towards a steady increase in the power of the Board of Education to press for change, partly through the direct exercise of the power of the purse, partly through the influence of its advice upon the action of the local authorities.

Secondly, we have realised more fully than heretofore the need for greater unity of purpose in the different grades of education and the dependence of what is attempted at one stage upon what has been accomplished in another. For example, we have recognised the fact that technical instruction cannot be built up as a detached system by itself. In its higher forms it has to rest upon a long and carefully organised course of secondary education; in its more elementary grades upon a sound foundation given in the primary and higher-grade schools. The need of adjustment between the methods of teaching in the infant school and those employed in the junior classes of the senior school; the waste of effort caused by a sharp break of gauge at the junction between the public elementary and the older type of secondary school; the impossibility of making an effective reform in the curriculum of preparatory schools without a modification of the requirements of the entrance and scholarship examinations at the Public schools, are all frontier questions, the consideration of which has forced upon us the need for greater unity of plan in our educational system. And in order to secure greater unity of plan, we are tending towards greater unity in educational administration. The central authority has been unified and entirely reorganised. In all parts of the country new local authorities have been set up with powers which embrace primary, secondary, and technical education.

Thirdly, a wholly new stress has been laid upon the physical side of education. The reports of the Scottish Royal Commission on Physical Training, 1903, and of the Inter-Departmental Committee on Physical Deterioration, 1904, have helped us to see the whole question of school work in a new perspective. A systematic physical training must be regarded as an essential part of the daily work of every school, and will be found as beneficial to the intellectual and moral development of the scholars as to their bodily condition. For guidance in the educational treatment of every child according to its physical need; for the detection of defects in eyesight, in hearing, and in teeth; for marking the symptoms of organic disease, we require systematic medical inspection of all school children at periodical intervals, especially in schools in poorer districts. The attention of great numbers of the teachers is already directed to these matters, and with a fuller training in hygiene they would be able to make a considerable number of the necessary observations for the use of the medical inspectors who would visit the schools at such intervals as the special circumstances required. The crux of the difficulty lies in getting the parent to act upon the medical inspector's report. But the majority of parents, especially when interest in the matter was shown by a personal visit to the home, would gladly take the necessary steps to secure the medical treatment required. Where help was necessary, it would not be difficult, through the co-operation of charitable agencies, to secure it. And in cases of obstinate neglect, the law should severely remind the parent of his responsibility. But to improve the schools and the physical care of the school children is not sufficient without reforming the state of many of their homes also, and without a great change in some of the conditions of industrial employment. Where the insufficient feeding or the wrong feeding of some of the children is found to defeat the work of the school, the real cure of the mischief lies in dealing with the parents, with their economic weakness or ignorance or wastefulness or insensibility, as the case may be. Where the children come to school exhausted by the strain of long and late employment out of school hours, the remedy has to be found in stringent regulation of the use of juvenile labour, and, so far as may be,

in the prohibition of those forms of premature wage-earning which are fatal to the gaining of industrial efficiency in later years. Thus, at point after point purely educational questions are implicated with economic and social problems, and we are forced to the conclusion that educational reform involves the intrepid handling of evils which lie outside the class room and affect the home life and economic welfare of parents and children alike.

Taken together, these developments in English opinion with regard to educational matters are significant and encouraging. They mean that the nation is beginning to look at the whole question from a new point of view and with a fresh attitude of mind. We have realised that our old standards of educational provision are quite inadequate to meet the new and more exacting requirements of the present time. To argue that England needs educational reform is no longer necessary: every responsible person admits it. Towards accomplishing that reform a fair beginning has already been made. But the real questions now before us are—What forms of education will best serve our special national needs? How much of our old tradition and educational machinery can we safely carry over into the new system? What will it cost us to put our national education into first-rate order? And by what system of taxation will the indispensable minimum of expenditure best be met? Fortunately it so happens that educational thought all over the world has taken a turn which predisposes English people to look with greater favour than heretofore on plans for systematic national training. The besetting weakness of the movement for the extension of popular education, from the beginnings of the French Revolution to quite recent days, has been its disregard of the educational value of practical handwork, its proneness to attach undue importance to bookish studies, and its inability to get out of the rut of the old scholastic tradition. The latter had really aimed at recruiting the literary professions, and had paid little attention to the needs of the industrial and commercial callings. It was, therefore, full of misleading precedents for a new educational movement which aimed at training the whole nation, including the diverse categories of its citizens, for the various tasks of modern life. Englishmen felt this objection very strongly. They did not believe that a purely bookish kind of schooling would furnish the required training of character and of practical aptitudes. Hence England stood out as, in the main, a stubborn opponent of the rather shallow popular theory of education. But the new phase of educational thought is full of criticism of the old bookish view of school work. The result is that England has never before been so nearly in full sympathy with the main current of modern thought on education as she is to-day. The characteristically English standpoint has always been that, in planning a course of education for anyone, you must keep the actual needs of his or her future life-work steadily in view; that education is not a question by itself, but one aspect of the whole social problem; and that, therefore, before deciding what kinds of education ought to be given in the schools of the nation, you must have a clear conception of the social structure which you wish to see built up by the individuals whom you propose to train. This is the view which has been taken by all the profounder English writers on education, such as Robert Owen, Carlyle, and Ruskin. But what may be called the old democratic theorists were apt to shirk this practical side of the matter. They acted on the belief that if you only started schools for all, and taught the rudiments of a literary education to everybody, the rest of the problem would look after itself. But the new turn in educational thought has changed the position. All the current educational theories lay stress upon the social aspects of education; upon the importance of making the schools prepare the children for citizenship, and for individual efficiency in this or that type of future calling; and upon the need of dovetailing educational discipline into the practical tasks of life. This is congenial to the English point of view. It predisposes English people to pay a quite unwonted measure of attention to educational theories. And thus caught at last in the web of thought on this difficult problem, Englishmen are being made to realise what foolish philistines they have been all these years in despising the service which careful educational organisation can render to national health, industry, and commerce. Nor does the process of salutary enlightenment end

here. The Englishman is being compelled to admit that, just as higher technical education can only flourish upon a basis of efficient secondary education, so, too, all practical training for the duties of life is facilitated and furthered by a liberal education during the early and impressionable years of childhood. This is the conclusion which, because of its inevitable expense and because of its interference with cherished class prejudices, the Englishman most reluctantly allows himself to reach. But he is being forced to reach it, and one sign of his reaching it is the new attitude of mind with which he approaches the question of elementary education. The old class view of the question is gradually fading away, and in its place, out of the blurred confusion of the dissolving view, we may hope, sooner or later, to see emerge in clear-cut outline the definite form of a national conception of education—national in its range, national in its unity of purpose, and national in its insistence upon personal obligation towards the State in return for the benefits which the State confers upon each of its citizens.

This great change has not yet come. It is hard to see any sign at present of a strengthening of national purpose and of the sense of individual obligation to the State, though this is the psychological pre-requisite to any effective handling of the problem of national education. But these things come not by observation. That such a change will come I, for one, strongly believe. But all that we can say at present is that the recent movement of educational thought in England has significantly weakened or cleared away some of the chief obstructions to the general acceptance of a national view of what education must mean in an efficient modern State.

The old English idea was that each class ought to have its own educational arrangements, those for the poor being a matter of charity, and the rest primarily a private concern of the families, with such help as old endowments might provide. The idea now prevalent in the progressive parts of the world, and notably in Germany and Japan, is that education from top to bottom is, first and foremost, a public concern, a national affair rightly subjected to national supervision. By slow degrees we in England are giving up our old idea and are moving towards a new standpoint, from which, in educational matters, a synthesis of State action and of individual initiative is seen to be desirable, and from which again a bureaucratic monopoly is seen to be as mischievous as are the disorders of *laissez-faire*.

From the old view, that each class ought to have its own educational arrangements, it followed that we have had in England three educational systems which were virtually distinct. That for the poor was narrow and brief; that for the middle class was imperfect in organisation, stunted in its higher stages, and cut off from many of the finer traditions of culture; that for the upper class was for the most part a training in manners, and barely touched by the new ideas which had sprung from the advance of physical science and from the application of science to industry, commerce and questions of social betterment. In broad outline these three separate educational systems still remain, but wave after wave of change breaks over them and obliterates their sharp distinctions. At each extremity there has been a great widening of educational purpose. The public elementary schools, once regarded as the schools for the poor only, have broadened out into something which is clearly destined to serve as a common basis for all but a small fragment of the whole educational system. At the other end of the line the Public schools have rapidly expanded, with the result that they now bring together as boarders the boys of nearly all the well-to-do families in the country, irrespective of denominational differences and of many social distinctions which in former days forbade such amalgamation. The midway schools, which used to serve the needs of the old middle class and, when in competent hands, rendered a great public service, are being hemmed into a smaller space by the expansion of the school systems above and below them, and are suffering from this double competition. The result is that friction has been set up nearly everywhere between the upper edge of the elementary school system and the survivals of the middle-class schools, and that every year an increasing number of the latter are shifted into a closer connection with the public elementary schools, so as to serve as what may be called continuation departments to them, instead of being, as in old days, virtually

separate class institutions complete in themselves. Through the pressure of a similar social change, the Public school curricula have been broadened so as to meet the needs of their new and wider *clientèle*. The old classical tradition has been found inadequate to meet the more varied needs of the new situation. The old classical monopoly, though still exerting undue influence over the scholarship and entrance examinations at the Public schools, has lost its former power. Modern studies steadily gain ground. Physical science and engineering have asserted their claims. The Public schools are gradually adjusting themselves to the requirements of business life in its new and more scientific forms, as well as to the needs of boys who are destined for the older professions.

The first result of these educational changes in England is social fusion. Old barriers of separation are melting away. Old prejudices, injurious to social unity, are lessened. English social life is readjusting itself to new economic conditions and, responding to the new impulse, the schools are hastening the change. But the second result is foginess in educational aims. Both the public elementary school on the one hand, and the Public school on the other, attract such a variety of pupils, with such diverse prospects in life and from so many different kinds of home, that it is increasingly difficult for either of them to have a clear-cut purpose in preparing their pupils for the actual tasks which await them when school days are over. In the case of boys, moreover, a number of new callings require courses of intellectual preparation on other than those traditional lines which gave, in fact, a form of technical training for some of the older professions. In the case of girls the same difficulty arises through uncertainty whether to prepare for married life or for the examination requirements of a professional career. In such circumstances schools, when challenged to define their criterion of educational efficiency, are apt to lay stress upon the importance of moral 'tone' and *esprit de corps*. However just may be this emphasis upon the moral side of education, moral training is apt to become unreal and lacking in clear purpose unless it is associated with definite preparation, intellectual and otherwise, for actual tasks in life. It gets conventional, or refers too exclusively to the artificial and temporary conditions of school-life, and sometimes in practice signifies a code of manners and of bearing rather than vital principles of conduct. Hence comes the growing force of the new movement in educational thought which calls for closer adjustment of school work to the actual tasks of adult life. Schools are at present too little concerned in the question how each individual pupil is likely to earn his living, and are too apt to act as if their responsibility were confined to bringing all their scholars through the appointed course, and to preparing as many as possible of them to enter successfully upon some further stage of education, as though the definite choice of a career could in all cases be safely or wisely thus postponed. The demand that the schools should become more practical in their aim without becoming narrowly utilitarian grows stronger year by year. Difficult as such a demand is to satisfy, there is nothing unreasonable in it; yet it cannot be met without a franker recognition of the probable after-career of the pupils than is at present usual or likely to be popular. But one great cause of the democratic movement in favour of better schools for the people, and for widening the social connection of the Public schools, is that numbers of parents want their children to start life on a higher plane than they did themselves, and to earn their living by an occupation better thought of socially than their own. Any serious attempt, however, to make all schools prepare more definitely for the practical tasks of life would involve the assumption, which of course is roughly accurate, that children will for the most part enter into occupations similar to those followed by their parents, and that educational provision must be made for them accordingly. Now it is clear that in a time of swift economic change like the present such an assumption would break down in a considerable number of cases, and that those would be the cases of the greatest educational promise. For example, it would be absurd to assume that, under present conditions of land tenure and cultivation, all the children of farm labourers in rural schools will wish to remain on the land. Thus, there are the makings of a conflict between those plans of education which rest upon the principle that every child should be given a chance 'to rise in the

world,' and those plans which presuppose a more stable social organisation and which seek to encourage specific preparation for the workshop and the farm, as well as for the office and the professions. The right solution will lie in securing for every child in town and country up to twelve years of age a humanising and individualising education, which will develop the physical powers, kindle the imagination and give a good preliminary training in accurate observation and in clearness of self-expression. In such a course the training of hand and eye and the intelligent study of nature will play as important a part intellectually as bookwork and linguistic discipline. At twelve years of age will begin the differentiation of training, provision being made, by scholarships and by sufficient allowances for maintenance, to secure so far as possible for every child, whatever the position of its parents, access to the type of education appropriate to its aptitude and promise.

But at present we are in an eddy of more or less conflicting purposes, and our difficulties are increased by the fact that different districts are in very different stages of economic development, some in the full current of change, others still in the grip of old ideas and traditions which have lost their force elsewhere. In some neighbourhoods the old idea that all education above a narrow stint of elementary instruction is a privilege for which full payment should be made by the family concerned, retains, in spite of simmering protest, a good deal of its old power. In others the new collective ideal of public education on equal terms of gratuity for all is the dominant, though not yet wholly victorious, force. In most districts the old and the new ways of looking at the matter are struggling on equal terms and with resulting compromise. Into this medley there has poured the new current of educational thought which runs counter to the vague aspirations of those who seemed to take it for granted that the mere establishment of new schools, whatever their curriculum, would remove the graver social ills. The new thought requires that schools should have a definite relationship to the social and economic position and prospects of the pupils. It calls for more workshop training in the elementary schools. It points to the failure of a too literary curriculum to give a right training for practical work. It is a timely protest against the besetting tendency of all rapidly organised modern systems of popular education to overcrowd the more literary occupations. It is really of all educational movements the most radical, because it seeks to raise handwork to a position of greater honour in the community and to lower the undue prestige of purely literary culture. But because it insists upon preparation for life, it is in some danger of unconsciously allying itself with the old view that education must at bottom be a class affair, and should vary from the first according to the position in life in which the children who are to receive it happen to have been born. And along with these movements of thought there is a steady growth of the conviction that in England the State should do more than in times past to control the education of its citizens. And towards increase of State control we find ourselves pushed by the growing burden of educational expenditure and by the need for increased subsidies from the Exchequer in relief of local rates.

Thus great changes are coming, and coming in the right way, by individual effort responding in many ways to a new sense of national need, as well as by a gradual reform from within of many old institutions which have struck their roots deep into the national life. Towards strengthening this new sense of responsibility on the part of the schools and universities which represent in the main the older tradition in English education much was done by that eminent scholar and eloquent writer, Sir Richard Jebb. And, if we extend our view to what is going forward in Scotland, Wales, and Ireland, the same impression is confirmed. It has been and is the good fortune of England to receive educational stimulus of different kinds from each of the other parts of the United Kingdom. Scotland, above all, has during the past century and a half taught us many lessons. And we have only ourselves to blame that we have not learnt from her many more. One of her lessons, that the higher educational opportunities should be brought within the reach of every lad of promise, we have at last taken to heart seriously, with already fruitful results. Nor ought it to be forgotten how much stimulus

and quickening of purpose we have derived from the zeal and courage of America, from the diligent pains, the thrifty but never parsimonious management and the skilfully directed efforts of German education; from the very practical patriotism of Denmark and from the brilliant academic renaissance in France. In education one nation is foolish to attempt a slavish copy of another, but still more foolish to refuse to learn from it. And the result of all these diverse influences is that much more than that is hopeful for the future is quietly taking place in English education than any one observer can realise.

The leaven is at work. If we were informed of a similarly fruitful movement in educational opinion in a foreign country we should be ready at once to admire and to draw a moral from it. Let us not deny ourselves the pleasure of deriving encouragement from what is taking place among us at home. It was indeed high time for a great change, for I suppose that no one who endeavours to look upon English education with a candid eye could fail to admit that in no other civilised country have so many otherwise intelligent people been habitually indifferent to education or unaware of what it may be able to do. In spite of the fact that the suggestions to teachers in the elementary schools, issued as a Blue-book by the Board of Education, has had a sale equal to that of a popular novel, I am afraid that great tracts of this habitual indifference still remain undisturbed; and it must be admitted that in England, as compared with the best of Scotland and Germany, the home still does little to co-operate with the work of the school; that manifold class separations have prevented the growth of unity in our school system; that we have been very wasteful of the more ordinary kinds of intellectual material; that we have done pitifully little to teach the mother tongue; that we have done far too little in our school lessons to kindle the power of imagination which, on social, on political and on economic grounds we greatly and urgently need; and that by our worship of examinations we too often encourage, on the part both of teachers and of learners, the wrong attitude of mind.

But nevertheless, on looking at the matter as a whole, we have good reason to feel that during the last ten years the mind of the nation towards educational matters has significantly changed, and that we have every reason to feel encouraged for the future. If truth be told, we are worried and puzzled at the questions involved. But I make bold to say that we are perfectly right to feel worried and puzzled—that the central difficulties of the whole matter are the outcome of a profound change in our mental outlook, due to scientific investigation and to an upthrust of new social forces and ideals; that our best chance of gradually finding a right solution for our difficulties lies in discarding the idea that somewhere in the world there is a magic formula in education which can heal our troubles; and that we should recognise the need of patient and systematic experiment in new educational methods and forms of training.

During the last two or three years it has been my duty, on the invitation of a number of local educational authorities, to study the working of many different kinds of school and the social and economic effects of various forms of educational effort in typically different parts of England. May I venture very briefly to summarise the conclusions and impressions which these inquiries have made upon my mind? In the first place, I am profoundly impressed by the differences between different districts in this country, differences in economic need and, what matters far more, in psychological outlook upon educational matters. If there is one country in the world where a rigid cut-and-dried State system would be quite inappropriate, it is this country. We cannot, therefore, be too grateful for the number of men and women all over the country, members of local authorities, teachers and other social workers, who are devoting to the question of the public welfare an amount of thought and time and money which is not surpassed in any other land. And we may be thankful for the fairness of mind and temperateness of judgment which mark their outlook on educational affairs.

I am also deeply impressed by the inevitably great expense which must be incurred in carrying out in an adequate manner any effective plan of national education. The expense will be far greater than has yet been realised. Yet we have so much educational leeway to make up that we are bound to incur this

expenditure. But great caution is required lest we get too far ahead of current opinion. It will be wise to spare no pains in carrying the mass of the people along with us, and in proving our case to the practical mind of the ratepayer. Things are moving fast. People listen to argument. When educational plans are put before them, they materially help the expert organiser by their practical criticisms. Many new educational efforts have been started during the last few years. No harm will come from a little slackening of the pace in administrative change. We may be content to watch the outcome of much that has been recently begun.

We still know too little about what is actually going on in England. The educational magazines have rendered a great service to us in supplying information, and every year they furnish us with fuller materials for a critical judgment as to what is going forward in a considerable number of schools. The Special Reports of the Board of Education are also a mine of information. But the limits of our exact knowledge of the actual work of English schools are still extraordinarily narrow. Too little of scientific value has yet been published about the work of the public elementary schools. And, to turn to another important part of our educational system, if anybody wished to say what the curriculum of all the great Public schools is at the present time, how much time is given in each form to each subject, how many exemptions are allowed, and what kinds and degrees of specialisation are permitted, he simply could not answer the question. He would have to content himself with the details of a few schools, and for the rest to put up with generalities. There is no adequate published account of what is actually the scheme of work in each of the great English Public schools. The nation is practically in the dark on the subject. We have no materials for accurate and detailed analysis of their present courses of study. One school does not know what another is doing. Parents do not know. The public does not know. And yet great changes have been made, and all manner of new plans are being tried. But there is no proper comparison of results.

It is much to be desired, therefore, that we should have a fuller record of what is actually going forward in English education of all grades at the present time. And this is a suitable occasion on which to plead for a systematic, periodic series of physical measurements of children in all schools. Such a series of measurements will form the only sound basis for generalisations as to the physical improvement or retrogression of the community. But, besides this, we need something like an inventory of present educational effort in England, intelligently written, and with a careful examination of its bearing upon the economic and social needs of the nation. We welcome in this connection the recent decision of the Board of Education to entrust his Majesty's inspectors with the new duty of taking wide surveys of educational work, and of considering the relation of what is done in schools to the needs of the communities in which the schools are situated. But is it too much to hope that from time to time the central authority will publish these reports and surveys, and that every teacher and every member of a local authority will be able to receive regularly, without trouble and without payment, each new number of the series from headquarters? We need much more cross-fertilisation of educational ideas. We have much to learn from the freedom with which the American Bureau of Education issues, without charge and abundantly, information to all who ask for it. The great thing is that we should not have things forced upon us by the central authority, but that we should do them willingly and gladly in our own way; and we are far more likely to do that if we are continuously thinking of the matter and refreshing and stimulating our minds by a knowledge of what has been actually accomplished in our own country and in other lands.

It is clear that we cannot hope to see all the desirable reforms and improvements in English education undertaken simultaneously. Financial considerations alone forbid any such ambitious scheme. It will be far better to concentrate on a few things at a time, and to do these thoroughly and well. And in selecting the parts of the problem upon which effort should thus be first concentrated, will it not be wise to look to the growing points in English education as we find it

to-day, and to encourage growth from those points, instead of wasting time on what may be regarded as dead tissue?

The following seem to be the chief growing points in English education at the present time:—

First, there is a new and striking keenness on the part of many intelligent workmen to secure improvements in the public elementary schools, to have smaller classes and more individual teaching in them and to have better staffing in the higher standards, so that there may be less marking time during the last years of the course. This same section of the artisan class further desires the provision of a new type of secondary or higher grade school connected with the elementary schools, and in sympathy with them, and providing a higher education up to about fifteen years of age. They wish to see the technical and physical education of the children who have just left the elementary day schools carried forward systematically in evening classes, well graded through each district and skilfully adjusted in point of curriculum and teaching to its economic and social needs. For adult workers, again, they desire a further education, which is not simply bread-winning and technical—excellent as that is—but which has a touch of imagination and humanity and civic idealism about it as well. I take it that this is one great and continuous line of light across the educational situation. It is a sign of the times that we ought to watch, one that we ought to welcome and encourage. Whatever is done along this line will stimulate further improvements along the line of secondary schools attended by the children of parents in somewhat easier circumstances. The middle class will quickly realise that it cannot afford to be distanced by the artisan class. When it once realises this it will seriously demand reform in the secondary day schools. And the latter, thus reformed, will be a boon not only to the professional classes but also to the most intelligent sons and daughters of the artisan class.

Then, further, no one, I think, can visit school after school without being impressed by the keenness and freshness of interest in those class-rooms where practical science work and manual work are being done. We are not here to plead for science against the humanities, or for the humanities against science, but I think we may rejoice to see a new and kindling interest in our education through the greater development of practical studies.

And, thirdly, it is striking how many of the great employers of labour, during the last two or three years, have shown a new and welcome interest in the problem of how best to encourage further education among their workpeople and apprentices. This interest is most striking in the case of the railway companies and the great engineering firms, and it is spreading from those firms to many other industries.

But if we are to help forward in the most effective and economical manner the educational movement which is thus already in existence in England, we need much more carefully planned and systematically watched educational experiments in order to see how to meet our social needs thriftily and efficiently. Such experiments should be thought out beforehand, scientifically planned and supervised, and continued for a sufficient period of years. Instances of failure should be as frankly recorded as those of success. And the results should be regularly circulated by authority, free of charge, among all recognised teachers and members of local authorities. Possibly in order to avoid difficulties which arise when undue publicity is given to the names of individual schools or teachers, it might be found expedient to record the results of each experiment under a number instead of under a name.

The first experiment which I would commend as greatly needed is one for the better classification of the children in public elementary schools with regard to their different rates of mental growth and different intellectual aptitudes. Valuable work on this subject is being done by Mr. Lauth. In our present system of elementary education do we not treat quite different types of children too much alike? The sifting out of the defective children is the beginning of a process which might well be carried much further. In the town of Mannheim the Superintendent of Schools has arranged a subsidiary department in the school, to which children of slower growth may be temporarily transferred for separate treatment

and teaching until such time as they are able to take their place again in the main department of the school. Of course, in many of our English elementary schools, where the numbers of children in each standard are very large, there are divisions, one for the quicker and one for the slower children. But do we not need to push this a great deal further, and to make much more distinction between different types of mind and rates of intellectual growth from the bottom of the school upwards? Any such reform means smaller classes in the urban schools and better staffing in the rural schools. These are the two essential reforms in our elementary education. Each of these reforms must be very expensive, so expensive that we ought to try by experiments to find out what we can do effectively to individualise the children by dividing classes differently for different parts of their work, by encouraging more private study on the part of the children and by massing groups of children together for certain subjects.

It would be an excellent thing if each great local authority would have two or three of its elementary schools set apart to work out the educational problem and the financial problem, which are really involved in giving every child in the elementary school an individual training suitable to its needs.

Then it is desirable that we should try in certain districts a new type of elementary school, with far more manual work in the curriculum, with a great deal of physical training, and with simpler aims in regard to the more literary studies. Much may be learnt from the industrial schools, and I cannot help feeling that, with all the good intentions in the world, the present curriculum of many of our elementary schools is too ambitious for the real needs of the children, and that the latter would get more good from something simpler and more practical.

Thirdly, we need a very careful working out of the best course of study and of training for higher grade schools attended by pupils between the years of twelve and fifteen—careful experiment as to how to adjust the studies in those schools to the real needs of different kinds of practical life, and at the same time how to keep fresh and strong a literary interest and feeling of civic duty.

Fourthly, we need carefully watched experiments as to the actual results of postponing the beginning of Latin as a regular school subject until twelve years of age. We wish to know how quickly children who begin Latin late can overtake those who have begun the language much earlier. We need to know more thoroughly than we do at present what such a change as the postponement of Latin until twelve would actually mean to the normal standard of scholarship at the top of the classical secondary schools. We need a careful comparison of the classical attainments actually reached in the Reform Gymnasien in Germany, where this system has for some years been on trial with good results, with the classical attainments of the boys at similar ages in our own classical schools. Further, the comparison should extend to the *general* attainments of the boys in the same two groups of schools, and not be limited to the department of classics. If it is possible to defer until twelve the beginning of Latin as a regular school subject, many difficulties arising from the present break of gauge between primary and secondary education will be greatly lessened.

I desire next to direct your attention to an urgent and extremely difficult problem in our English education—I mean the waste of intellectual power and the frequent injury to character which arise from children leaving the elementary school at thirteen or fourteen and then passing away altogether from discipline and educational care. The problem of the right education of boys and girls during adolescence is only just beginning to receive the attention which it deserves. But can we live in our great cities without having an uneasy feeling that modern conditions of city life and of city employment, with their opportunities for earning a comfortable wage quite early, and with their unwholesome excitements, are really imperilling the stamina of many of the boys who should be the recruits of our skilled industries, and of many girls who should grow up to be the mothers of good and healthy homes in the future? It is much to be feared that certain phases of modern industry, which depend on the practically unskilled employment of boys and girls who have recently left the elementary schools, are in

part parasitic in character, and get more than they ought to have, and more than their promoters realise they are getting, of the moral force and physical strength of the nation.

In the year 1901-2, of the whole population of London between fourteen and twenty-one, only 15 per cent. were actually in attendance at the continuation schools under the then London School Board. If we double that (and it is an excessive estimate) for the number in the evening classes under the then Technical Education Board, we arrive at the conclusion that out of the whole number of young people in London between fourteen and twenty-one years of age, less than a third were receiving educational care. In 1904, in Manchester, at least 14,000 boys and girls between fourteen and sixteen years of age were not in evening schools or day schools. The conclusion which is being forced, I think, on the majority of observers is that we cannot afford to allow this leakage to go on. We are in the position of people who have laid down a costly water-supply, but have then left a hole in the pipe just behind the tap. Mr. Creasey in his excellent book on 'Technical Education in Evening Schools,' and the authors of 'Studies of Boy Life in our Cities,' issued by the Toynbee Trust, agree that something must be done to require some kind of continued education during those critical years. Out of seventy-six teachers and experienced administrators in all parts of the country whom it has recently been my duty to consult, no fewer than fifty-two were in favour of some form of obligatory attendance at continuation classes.

But I am glad to say that during the last two years there has been a remarkable improvement in the organisation of evening schools in many industrial towns in this country—an improvement due to the labours of the local authorities and their organisers, and to the wise counsels of the Board of Education. The case of Halifax should be mentioned with special honour. Last year, in that town, of all the boys in the borough of thirteen, fourteen, and fifteen years of age who had left the day school, 69 per cent. were in the evening classes, and 96·7 per cent. of the boys enrolled were attending three evenings a week; 25 per cent. of them had not missed a single attendance, and 41 per cent. had made between 90 and 100 per cent. of attendances. This has been done, in the absence of any compulsory powers, by the skilful organisation and keen interest of the Borough Education Committee and of Mr. Crowther, the Principal of the Technical School. The results have been achieved by grading the schools skilfully, by offering wise inducements to punctual attendance and also by making the courses of study bear directly on the varied trades and needs of the borough. The position of the evening schools in the agricultural districts is much less promising. But even here there are grounds of encouragement. In the rural county of Cambridge there is an evening school in almost every parish and I believe I am right in saying that, as the result of many years of careful work and encouragement on the part of the County Education Committee, and Mr. Austin Keen, its Secretary, 60 per cent. of the boys who remain in the county after leaving the elementary schools are to be found pretty regularly attending the evening classes.

There are one or two cases of wise and liberal action on the part of employers of labour to which I will allude. At Messrs. Rowntree's cocoa works in this city all girls under seventeen are required to attend a school of domestic economy, cookery, and hygiene two hours a week, during work hours, in an excellently planned and well-taught school, maintained by the firm at its own expense in the works. There are three teachers; the school is under the supervision of the Board of Education; 520 girls are in attendance; and the results are most encouraging to those who have tried this valuable and epoch-making experiment. Messrs. Cadbury, of Bournville, who have done so much in other ways to promote the well-being of those whom they employ, require all their workpeople under fifteen to attend the gymnasium twice a week. At Messrs. Crosfield's, of Warrington, attendance at evening schools, greatly helped by the firm, is compulsory for all boys and girls under seventeen years of age (the hours of work with the firm being so short as to make this attendance possible without undue fatigue); and all boys and girls of fifteen (thirty boys and twenty-five girls) are sent to learn swimming at the town bath.

These individual cases of industrial betterment are especially valuable as pointing the way to reform, and as showing the lines on which public authority may hereafter wisely enforce a higher standard of educational and physical well-being among the young people of the nation. For, very great as is the value of this voluntary work, it yet does not touch that huge residuum which we feel is drifting off, after the elementary school, into physical and intellectual disorder, losing the habit of work, losing the habit of discipline, becoming casual, losing exactly the powers of mind, body, and character which are needed if a skilled trade is to be learned.

But it will be insufficient merely to make attendance at existing continuation schools compulsory unless we also touch the question of the hours of employment of juvenile workers. The remedy will lie in throwing a statutory obligation upon all employers of juvenile labour to facilitate the attendance of their young people up to seventeen years of age at evening classes without incurring physical overstrain. The local authority should act in concert with the employers and with the representatives of the workers in each trade in planning a course of study in the evening schools which will be technically useful to those who receive it and at the same time beneficial to them as citizens.

This is exactly the stage through which Germany has passed. Munich has especially distinguished itself under the administration of Dr. Georg Kerschensteiner, by its sensible and practical development of the civic as well as the technical side of continuation school work. The kingdom of Prussia is organising, by local option, in district after district, obligatory attendance at continuation schools, by throwing on the employer the duty of facilitating the attendance of his own workmen at such schools, and permitting the local authorities to make such attendance obligatory for boys, and, if they wish it, for girls, within such period of years as may seem to them suitable. In varying degrees, attendance at continuation schools is compulsory in a number of other German States, viz., Bavaria, Wurtemberg, Baden, Saxony, Saxe-Weimar, Saxe-Meiningen, Saxe-Coburg Gotha, and Hesse.

In Switzerland attendance at continuation schools is in part, if not wholly, obligatory in seventeen out of the twenty-five cantons for boys, and in one canton for girls. I should like to see a beginning made in England by some local authorities requiring attendance at a course of physical training for all boys and girls up to seventeen. But we must also quicken the intellectual power of the teaching in the primary schools by securing further opportunities of liberal education and of professional training for all teachers and by reducing the size of the larger classes. We must develop our secondary schools in order to spread a wider educational outlook among the employers and foremen. And these two changes, working together, will, I believe, steadily and at no distant time lead us to the conclusion that it is not only necessary but wise to make some measure of attendance at continuation schools obligatory for boys and girls until they are seventeen years of age, leaving the details to local option, but encouraging by a double grant those districts which adopt compulsory attendance.

There are three great names in educational history connected with the county in which we are met: Alcuin, the head of the great school at York, who organised for Charlemagne the palace school at Aachen; Roger Askham, of Kirby Wiske, near Northallerton, a friend of Lady Jane Grey, and the teacher of Queen Elizabeth, who among older writers on education was unsurpassed in his psychological analysis of the different types of mind with which the teacher has to deal; and Joseph Priestley, man of science, philosopher and teacher, who opened out for the middle classes a new ideal of modern secondary education, insisting that the studies of the secondary schools should be brought into real touch with the needs of modern civic life, and who wrote, perhaps, the best essay in the English language against any undue State monopoly in the control of national education.

Has not each of these great Yorkshire leaders his message for us to-day?—Alcuin to remind us that, whatever else is done, the nation must educate its leaders; Askham to remind us that, in order to individualise our scholars, we must distinguish between their aptitudes and natural rates of individual growth;

Priestley to remind us that the key of the situation lies in getting new ideas and greater keenness into the secondary schools, and that we should do nothing to weaken individual initiative and private experiment by taking any tempting short cuts offered by excessive State control.

The following Papers and Report were read :—

1. *Physical Education.* By Sir LAUDER BRUNTON, M.D., V.P.R.S.

Education ought to consist in the development of faculties which would otherwise remain latent. In order to be complete it should consist of three parts—physical, mental, and moral—and in the arrangement of these parts the object of development should be kept clearly in view, and they should not be allowed to degenerate into processes of cramming or routine. The brain is the organ through which the mind acts upon the body, but the body also reacts upon the brain and on the mind, and therefore mental education cannot be regarded as complete unless combined with physical education. Mental processes are only rendered evident to others by muscular action, or sometimes, to a slight extent, by secretion, e.g., tears. Muscles are set in action by nerves, which proceed from the nerve centres, spinal cord, basal ganglia, and cerebrum. The spinal cord presides over simple reflex action, the basal ganglia over complex involuntary co-ordinated movements, and the cerebrum over voluntary action. Physical education should be adapted to train all these structures : (1) The muscles, by simple movements frequently repeated; (2) the spinal cord and basal ganglia by both simple and complex movements, such as those of gymnastic apparatus; and (3) the highest voluntary centres by games, and especially games of ball, or by the Japanese system of ju-jitsu, wherein all of which rapid judgment and decision are requisite. In order that these organs should remain functionally active they require free circulation of blood and a free supply of air, and physical education requires training in respiratory movements and supervision of the circulation to see that no harm is done by over-exertion. Increased exercise also requires increased food; but not only must this be supplied in proper amount and proportion, but it must be digested and assimilated. Proper physical education is thus almost impossible without systematic medical inspection. A good deal of training may be done in rooms, but it is better carried on in the open air, and thus playgrounds are really as essential as schoolrooms. In order to obtain all the requisites for physical education a good deal can be done by the Board of Education and county councils; but a good deal will still depend upon voluntary agencies, and it is most essential that these should be able to work together so that each one shall be aware of the best methods as followed by others, and there shall be no overlapping. It is the object of the National League for Physical Education and Improvement to bring all bodies working for the good of the people into relationship with one another, and thus to ensure throughout the country a perfect system of physical education.

2. *Medical Inspection of Schools.* By Dr. ETHEL WILLIAMS.

3. *Physical Training in Denmark and its Application to English Needs.*
By Major SALMON.

Military gymnastics have greatly developed in Denmark, and the Swedish system is now adopted to the exclusion of every other for the schools throughout the country, it being found after long experience to be that of all others most suited to the needs of the people. It has now a strong hold on the national life. It is compulsory in all elementary and high schools, and is an integral part of every school-teacher's training, four to five hours a week being allotted to it at

the training colleges. The teacher's certificate includes a knowledge of swimming, and, wherever schools are within easy reach of the sea or baths, swimming takes the place of gymnastics during the summer months.

During the summer vacation a short course of one month for physical training is held at various centres to enable teachers to refresh their memories and to give instruction to those who did not have it during their college days. These courses are voluntary, but those attending are given free board and lodging besides railway passes. Many teachers avail themselves of these classes, and may attend them as often as they like under the same conditions.

There are at present fifty gymnasiums belonging to elementary schools in Copenhagen, and another three hundred divided amongst some three thousand schools outside the capital; they are steadily increasing. In the elementary school time-tables at least two hours a week are allotted to physical training for boys and girls under eleven years of age; those over eleven do three hours a week in many of the schools. Children found too weak to perform the exercises, owing to malnutrition or other causes, are brought to the notice of the authorities; they are then given a hot meal every other day at the school during the three winter months of January, February, and March. So much importance is attached to this physical training that in the eyes of the Danes an expense of this nature is well justified.

An essential feature of the Swedish system is its carefully considered sequence on a scientific basis within each lesson, one movement being such as to prepare the way for the next. By this progression, as the child gets older the exercises become more specialised, until the beginnings of real physical culture are reached.

Deep breathing exercises are done frequently between the others, and to prevent, so far as possible, the inhaling of particles of dust, a damp felt or sacking is passed over the floors before every lesson. It has been truly said that 'to breathe well means to live well, to live longer, and to live better.'

If this training is to be universally adopted in England in the elementary schools of every country, it must form a part of the curriculum of all would-be teachers in their training centres and colleges.

A great deal is now being done in Surrey, where the movement has become very popular amongst the teachers.

The Swedish system has the great advantage of not being dependent on a gymnasium, though a building fitted up with apparatus is very desirable. The fact that free-standing exercises constitute an essential part of the system puts it within reach of everyone.

It is suitable for all ages and for both sexes; it brings about a uniform development of the entire body. Girls who have had the advantage of such training are thereby made more fitted to be the mothers of a future healthy generation; its national significance cannot be over-estimated.

Baron Nils Posse, now Director of the Posse Gymnasium in Boston, says of it: 'Swedish gymnastics must be the basis of all rational gymnastics, since to-day it is the only system whose details have been elucidated by, and derived from, mechanics, anatomy, physiology, psychology, and whose theory has survived the scrutiny of scientists all over the world. So that, whatever the name or form of the gymnastics of the future, the Swedish system will be its frame, as even now we see it transforming and absorbing all so-called systems.'

4. *The Workers' Educational Association: an Experiment in the Organisation of Working-class Education.* By H. O. MEREDITH, M.A.

The Association was founded in 1903 to organise the advanced education of working men. Preparatory work—conferences and the like—occupied the first two years of its existence, but in the winter of 1905-6 it had some twelve local associations at work, with prospect of many more to follow.

Among the difficulties of the Association may be noted that of constructing courses of study which shall be within the powers and leisure of the mass of wage-

earners aged from seventeen to forty. This difficulty is perhaps even more fundamental than that of organising—at least, so far the Association has found it so.

The root idea of the Association is to wed to the existing University Extension movement a system of local associations or guilds which shall comprise all students and interested persons, together with delegates from all working-class and educational organisations in the neighbourhood. The *object* is to supply some substitute for the collegiate basis of university life, to make work continuous and effective, and to prevent overlapping. The *hope* is that, at least in the larger towns, these guilds may grow eventually into working men's colleges of the London type.

Besides this organising work, the Association is already engaged in collecting information on various educational problems. It is hoped that with the spread of its local guilds this may become an important department of its work.

The Association is manned and officered by artisans and clerks, who have so far done all the work of note that has been accomplished.

5. *The Education of Wage-earners of School Age.*
By Mrs. M. E. MACDONALD.

6. *Report on the Conditions of Health Essential to the Carrying on of the Work of Instruction in Schools.*—See Reports, p. 433.

FRIDAY, AUGUST 3.

The following Report and Papers were read:—

1. *Report on the Courses of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.*—See Reports, p. 438.

2. *The Balance of Subjects in the Curricula of Elementary Schools.*
By CYRIL JACKSON.

3. *Adapting Rural Education to the Needs of Rural Life.*
By T. S. DYNOND, F.C.S.

4. *Primary School Problems.*—(a) *Balance of Curriculum*; (b) *Training of Teachers.* By Principal A. BURRELL, M.A.

(a) Before balancing the curriculum it is imperative to group the subjects, not for the purpose of correlation in teaching, but simply that it may be understood under what head a subject is to be drafted. The grouping of subjects suggested would be as follows:—

1. *Physical Work.*—The following come under consideration: Dress, ventilation of rooms, games, central playing grounds, and all that belongs to the understanding, care, and training of the body.

2. *Tool Work.*—Tools are means of shortening and perfecting labour. The pen, the pencil, the ruler, the brush, the scale, compasses, carpenters' and joiners' tools, the needle (for boys), and such tools as may be required for boys of special aptitudes are to be instruments of skill and alertness.

3. *Geographical Work.*—As history is based on geography, the two are considered together. (a) The map and the lantern. (b) The main features of physical

geography, the inventions and processes in use, and the most pressing questions and problems. (This is to take the place of the chemical or physical laboratory in early days of school.) (c) The frequent reading of guide-books, books of travel and exploration, and books on the flora and fauna of great divisions of the globe. (d) History, taught on the concentric system.

4. *English Work*, including reading, spelling, composition, and literature.
5. *Elementary Mathematics*, chiefly mental.
6. *Singing, Speaking, and Voice Production*.

It will be seen that the following omissions or changes are suggested: (i) A second language is omitted. (ii) All but elementary mathematics are omitted. (iii) All definite instruction in chemistry, apart from geographical lessons, is omitted. (iv) All higher grammar is omitted. (v) Much more is demanded under the heads of physical work, tool work, and geographical work.

The subjects thus grouped would, out of a possible thirty-two hours or lessons, receive the following: Physical, six; tool work, six; geographical, eight; English, five; mathematics, five; singing, two.

(b) The training of teachers for this work. Demand should be made for (1) a preliminary examination to test general knowledge and fitness for the work, such examination not to take place later than the beginning of the seventeenth year. (2) A standard of measurement and health analogous to that demanded by the Army and Navy.

On entry into training colleges the work should be grouped under the headings referred to before.

1. Physical work should include (a) a grounding in hygiene, anthropometry, elementary physiology (a school-medical training). (b) a practical knowledge of drill and some games.

2. Tool work should include training in the use of tools and a practical knowledge of two manual training subjects; a large increase in the time devoted to drawing (blackboard and other).

3. Geographical work should include elementary science, map drawing, wide reading in suitable libraries.

4. English work should include a good deal of memorising and wider reading.

5. Elementary mathematics should not go beyond the practical mathematics demanded by the other groups.

6. Singing, &c., should include voice-production, theoretical and practical.

There should also be a separate study of the art of description.

It will be seen that the following omissions or changes are suggested: (1) a dropping of most of the psychology and theory of education; (2) a dropping of advanced grammar; (3) a dropping of advanced mathematics and science; (4) a large increase in drawing work; (5) a large increase in oral work.

It is further recommended that all students be compelled: (1) to study a language other than English; (2) to enter for a teacher's degree, the examination for which should be based on the above suggestions, should be to a large extent oral, and should carry with it differentiation of students into those who are awarded a degree, a first-class, second-class, third-class, or a certificate.

5. *The Training of Primary Teachers.* By Professor J. A. GREEN, B.A.

Educational changes are at present tending to throw greater responsibilities on local authorities and on teachers. The underlying idea is that schools should be specially adapted to their environment. Their business is to help in the process which makes socially efficient men and women of the children. The school is the chief formal instrument to that end; and as its aims and methods are under control, the social mind may there express itself to an extent proportionate to the efficiency of its agents—the teachers.

The education and training of teachers is therefore of prime importance. Great

changes in educational policy, unless accompanied by changes in the methods of making teachers, may be largely ineffective. A professional training fitted for a mechanical view of the teacher's work and mechanical methods of appraising its worth are vicious so soon as the official yardstick is transformed into pious counsels addressed to the intelligent freeman. The teacher has now been freed, but in many cases he does not know how to use his freedom.

In the new circumstances is it not necessary to think out afresh the training-college system? There have been momentous changes already. These are designed to raise the average status of the rank-and-file. Training colleges are projected which shall offer places enough for every man and woman who can reach the third-class standard of the King's Scholarship examination. This is a lamentably low standard, but of course the teachers will be all the better for the training-college opportunity. We may note, however, that the stimulus to effort is gone, and of course the third-class will form a larger proportion of the King's Scholarship list than ever. After two years in the training college the certificate examination follows. All classification has been done away with in this case; and inasmuch as the average attainment of candidates will be lower, the old meaning of the words 'trained and certificated teacher' will be altered.

It may yet be true that the average primary teacher will be better educated and better trained than in the past, and so far the changes are commendably conceived; but on the whole they seem destined to bring about a dead-level of mediocrity. They do not seem calculated to discover the best minds, although it is to them we must look for progress. We may admit that the training colleges have as their first duty to provide the rank-and-file of the profession. To turn out an efficient class-teacher in the short space of time available is in itself a considerable task. The schools want men who can carry out the plans of others with some intelligence; men who can control and stimulate fairly large classes; men who can work loyally towards an end laid down for the whole school by its head.

The training colleges have only two years in which to work, and three-fourths of this time have to be given to the general education of the students. Surely, then, their training work should centre in the practising schools, and the problem of stimulating a group of forty children to continued and purposeful activity should be the chief object of attack. The larger questions of general school organisation might be left to a later stage. The students have to gain their footing in the class-room first, and they have little enough time for that. The fact that it is life that educates should be expressed in the organisation of a practising school where formal exercises are replaced by activities which mean something to the children. Give the student in training the right point of view; let him see it worked out in the school to which he is attached, and in which he is to work until he understands it. Concentrated thought and practice will do much more for him than the present attempt to deal with the whole problem of school organisation, practice, and direction can do. Training at present tends to become too booky and unintelligent. Its effects are rapidly whittled away under the pressure of practical work. Thought should be centred upon the problem of the fruitful organisation of the lives of children during the hours spent in school. Actual experience teaches in a moment what a hundred lessons will not convey. Lectures should aim at opening the students' eyes rather than at *ex cathedra* pronouncements. In training teachers, the point of view is the essential thing to establish.

But so far we have been concerned only with the rank-and-file. What of those whose responsibilities are wider—the men in whose hands the direction of the school, as a whole, is to fall? Their selection should depend on some less mechanical principle than that of seniority. The man who has been longest a class teacher may be the worst possible person to take up the larger work. The headmaster ought, of course, to have proved his capacity in the class-room; but a man may be excellent in carrying out other folks' plans, yet quite incapable of devising them himself. The point of view which regards each school as an organism having an individuality, a special character derived from and adjusted to the environment in which it is placed, makes demands on headmasters which mere class-room experience cannot give.

One of the weakest sides of our present training-college system is the fact that it does so little to develop what may be called post-graduate professional study. This might be fostered by requiring evidence thereof in all candidates ambitious of promotion. Men who have been out of college two years or longer might be encouraged to offer themselves for a higher professional examination based on a liberal view of the profession. Success therein might be rewarded by scholarships enabling those who desired to follow courses of a higher professional character at the universities. All the universities have organised schools of education, and I can imagine no better work for these schools than that which some such scheme would give them. The course of study should be broadly professional—in addition to the history and theory of education, it might well include economics and sociology. Above all, it should be associated with the experimental school. To enter into the work of such a school a certain ripeness is wanted. The average student in training is intellectually much too raw, and he has not got the professional grip which would come after two or three years' intelligent class-room work.

The head of a school should have some idea of the educational system as a whole. He should grasp the purpose of it all, and thus understand how to adjust his own school to the general scheme as well as to the local environment. Having gone through such a course as that suggested, we might reasonably expect him to organise his school with some insight into social needs and in the spirit of a trained inquirer.

6. *School Training for Home Duties of Women.*

By Professor A. SMITHELLS, F.R.S.

It is difficult to regard any work as more important for the world's welfare than that which falls to the woman who has to manage a home. We are, I think, all agreed that it is work for which training, somewhere and at some time, is in the highest degree desirable. Traditionally this training is provided by an informal apprenticeship in the home. As a matter of fact, among the vast multitude whose daughters have to go to work it is hardly provided at all; among the rest it is often very imperfectly provided. It would be difficult to estimate the evils that result from this state of things. The only remedy is to make provision for the training outside the home, and there seems to be no reason why it should not be provided at school; beyond this, that school time is fully occupied with other things, and the children do not stay long enough. The question, as it affects children of the poorer classes, who leave school early, is beyond the scope of this contribution, but I should like to say that in the primary school I would, with a very light heart, sacrifice a good deal of what is now learned, for some simple sane instruction in the elements of the household arts and in the inculcation of cleanly and orderly habits of living. We seem to have made a fetish of the three R's and entirely lost our sense of proportion when we take the money of the State to apply what we call education to the children of the poor.

I wish, however, to deal with a different class of the community and a different grade of school—with girls who are better off and are in secondary schools. It is commonly held that such girls should be trained entirely at home in what relates to the management of the home. From this view I dissent emphatically for two reasons. In the first place the homes in question are often very much worse managed, and the seat of much more ignorance, prejudice, and folly, than their presiding geniuses have any idea of. It is not the last word of commendation, not a guarantee of perfection, for a girl to say, 'I learnt that from my mother; she learnt it from hers.' Who is there that has not suffered from such revered traditions in the field of cookery, to take a single prosaic example? All practical arts were once learned in this way, and we are tenacious of the system in this country. Some of our industries are perishing for no other reason than that traditional methods of work handed down from one generation to another are being obstinately adhered to.

In the second place I dissent from the view that all which relates to the

management of the home should be learned in the home, because it perpetuates a severance between the work of school and the real business of life. We are living in a period of educational revolution, and, so far as I can see, nothing is more prominent in it than the determination that school studies shall take what is called a more practical turn. This is often regarded as a philistine movement, and the pedants are sore afraid. But the engineers determined to dethrone Euclid, and they have done it. Rule, compasses, set-square, and protractor—with these base mechanic tools does the young pupil now enter upon his study of geometry, even in the precincts of our great public schools. The power to *speak* the French and German languages, too, is now hardly less esteemed than the learned dumbness formerly induced by a surfeit of their irregular verbs.

I wish to see some like changes made in the teaching of things which are specially important to women. I would go a long way and make such changes extend right through the course of education to the end of the university career.

The management of the home and the training of children—these are briefly the topics. The subject is much too vast to discuss as a whole, and I will only take part of it; but of the whole I may say that I shall not be content until I see these matters given at least as important a position in our educational system as the training of doctors or engineers.

The part of the subject to which I have given serious attention, and on which I feel any claim to speak, relates to the teaching of science. For many years past I have endeavoured to further the teaching to girls and women of something in the nature of science which shall be of real value in relation to affairs of the household. My object is not merely utilitarian. I start with this fundamental conviction, that no man's and no woman's work is what it should be unless it engages and exercises as fully as possible his or her powers of understanding, unless it acquires an intellectual interest and gives that pleasure which is only possible to one who is working in the light of knowledge. I need hardly insist that the household is truly a realm of applied science which our educational system has allowed to remain a realm of rule-of-thumb and drudgery. I do not see the complete remedy for this in the teaching of unqualified science. One may acknowledge gratefully that excellent progress has been made in the teaching of science in girls' schools. When this is well done one great thing is achieved, which may indeed be considered the greatest thing that science can achieve—a scientific habit of mind is imparted. If this is done, if the experimental method has been faithfully taught, we have the emancipation from rule-of-thumb, the mind is set free, and all we want now is its application to a field of useful knowledge.

I know of no sphere of human activity that more abundantly illustrates the unscientific attitude of mind than the household. Think of the common phrases—'It has gone wrong; it won't work; the oven won't heat; the jelly won't set; the meat won't keep; it has gone bad; the fire won't draw.' This is the language of superstition, for the thoughts behind are usually those of superetition. A demon of perversity—a mere chance happening—is implied behind it all. In how many houses will you not see a poker at times laid across the fire-bars to make the fire draw! This is certainly most interesting, for it is a survival from the days when people honestly believed that the sign of the Cross made by the poker across the bars exorcised the demon in the chimney. Think of the mismanagement of gas-heating and gas-lighting appliances, of the waste of money in patent nostrums of every kind, thrust upon us by much advertising, of the suffering that arises from crass ignorance of sanitation. Surely there is room for improvement; surely it is worth considering whether we might not do more to let a little additional intellectual light into the domestic laboratory.

As I have said, I do not think unqualified science will suffice. The science that is taught in our schools still remains for the most part formal and academic in its scope, and it is surprising to find how absolutely detached this science usually is from the concerns of the household and of common life. Schoolmistresses may be found in any number who have taken high degrees in science, yet can give you no intelligible account of the hot-water system of an ordinary house, cannot tell you what it is that yeast acts upon when it is mixed with dough, and have no opinion

as to whether a hand-mirror is a satisfactory test for a damp bed. They do not know why washing soda goes white or brass grows green. They think that dry cleaning is done without using liquids, and that salts of sorrel have some unique and inscrutable action upon ink-stains. They know nothing of gas meters, filters, or clinical thermometers, and are paralysed before a smoky chimney. Yet these people are learned about the oxides of nitrogen and the chlorides of phosphorus, the oxidation of secondary alcohols and the tests for cadmium.

Whilst science of this formal kind is being dispensed in certain schools and to certain kinds of pupils, there is something of a different kind being done in other schools to other pupils. The need for knowledge of more mundane and practical matters is fully realised, and we have long had with us the teaching of this under a variety of names. Domestic economy and hygiene are the names most commonly attached. Here we have the other extreme—science, properly so called, scientific method, scientific discipline, rationally connected knowledge, are here practically excluded. The reasoning powers are in abeyance, and the pupil learns a miscellaneous assortment of facts—tags of knowledge borrowed from physics, chemistry, and physiology, and laid down by authority. ‘Caraway seeds are largely imported from Holland, and are much used for flavouring confectionery, cordials, &c. They are the seeds of the *Carum carui*, a plant somewhat similar to the carrot and parsnip.’ ‘There is found in tea and coffee an astringent substance which gives the well-known bitter taste to the infusions when they are allowed to “stew.” In the case of tea it is known as *tannin*, and forms from 13 to 20 per cent. of the dried tea-leaf. In coffee it is called *caffeic* or *caffio-tannic acid*, but its amount is much less than the tannin in tea.’ And so on and so on. This is the sort of thing which has been offered as useful knowledge for the household. It is sorry stuff, and small wonder that it has produced nothing but nausea in the pupils and elicited nothing but ridicule from those who think that this is what we are aiming at.

I am convinced that there is a more excellent way. I am convinced that it is possible to develop a science of the household which is free from the pedantry of the formal science that has prevailed in one place, and free from the stale, flat, and unprofitable memorising of dietetic statistics that has been customary in the other. I have found it possible, as many others have done, to arrange a course of science lessons in which scientific discipline and scientific method can be inculcated by simple experimental work, based entirely on matters of the household and of daily life; where the information acquired is truly useful knowledge; and where the minds of the pupils are awakened to the fact that the household is, as I have said before, a laboratory of applied science that may constantly engage the intelligence. Syllabuses of this kind of work have been before the public for a long time, and among the earliest and best are those framed by Mr. Heller. We may call the subject domestic science. It is compounded of physics, chemistry, physiology, bacteriology; but these are hard names for simple things, and I prefer to suppress them.

Along with the teaching of domestic science in girls' schools I am anxious to see the teaching of domestic arts. I want to see a kitchen and laundry, as well as a laboratory. I want to see the teacher of domestic science well trained in the domestic arts and the teacher of domestic arts well trained in domestic science. In that case girls who have had their training in domestic science will in the later stage of their school career proceed to the practice of the domestic arts under the most favourable conditions, and their teachers will be able to play into each others hands and give unity and continuity to the scheme of training. In this way I believe you may do something that is beyond the province of home training and is yet well worth doing. It seems to me quite as unreasonable to say that a girl will learn in the home all she needs to know about the household as to say of a boy that he will learn in the workshop all he needs to know of engineering. I submit that there is a vast undeveloped intellectual region connected with the domestic work of women. I have alluded only to a small part of it, and perhaps not to the most important, for I have said nothing of the nurture and training of children. I do not undervalue home training; I am not so inhuman as not to

recognise that it must always remain the most potent element in the problem ; but I see no irreverence in suggesting that it may be greatly and beneficially supplemented in the school. I say, again, that it is impossible to estimate the evils that accrue from mismanaged homes, and I have lived long enough to know how greatly efficiency in all practical arts may be furthered by well-directed intelligence. I feel fully justified, therefore, in entertaining high expectations of the benefits to be derived from linking the education of girls much more definitely and thoroughly to what will normally be the chief business of their lives.

7. *School Training for Home Duties of Women.*
By Professor H. E. ARMSTRONG, F.R.S.

8. *The Training of the Teacher of Domestic Science.*
By Miss MARY E. MARSDEN.

In the early days of domestic science teaching almost the only qualification demanded of the teacher was the power of skilful manipulation. Much more is expected of the domestic science teacher of to-day than of her predecessor. Not only must she be proficient in the arts she practises, but she must be able to give reasons based on scientific knowledge for the processes she employs. She must understand something of child-nature and the laws of mental development, so that she may make the work progressive and encourage thought and initiative in her pupils, rather than unthinking imitation.

These increased demands on the present teacher of domestic science can be met, in the first place, by training as teachers only those who have had a good previous education. Students who have had a good secondary education are those best fitted for the work. The education given at a public high school in which careful training in the general principles of elementary science is included is an excellent basis for the special training in domestic science.

It is further desirable that, as a test of general knowledge, students should have passed some examination such as that of the London University Matriculation, or the Senior Local Examination of the Oxford or Cambridge Universities.

The ideal preparation for a Domestic Science Course would be a science degree followed by the special training in domestic science. Until, however, the salaries have reached a much higher rate for teachers as well as for organisers of domestic science, this will not be practicable. The salaries of those engaged in the arduous and responsible work of the training of domestic science teachers are very low in comparison to the salaries paid to those who simply teach children.

So far as I have been able to learn, the London University, at the Goldsmiths' Training College, is the only authority that has offered for the teaching of domestic science an initial salary proportionate to the work. If our training schools are to be efficiently staffed, educational authorities must offer considerably higher salaries than those given at the present time. The teacher of domestic science cannot afford to do her work mainly from philanthropic motives.

In the meantime, however, it rests with the training schools to require a higher standard in their entrance examinations. From the fact that some training schools require no educational test, or an extremely low one, some people, including many headmistresses, have been led to believe that the girl whose attainments at school have been below the average can take up domestic science. This is an entirely wrong idea ; such a girl is inevitably a failure as a teacher. There is one development of domestic science teaching which especially demands that the teacher shall have a good secondary education. I refer to domestic science teaching in the higher type of secondary schools (that is, those in which the pupils are not mainly drawn from elementary schools). If domestic science is to rank with other subjects in the curricula of such schools, the teacher must take equal educational and social rank with her colleagues. She can only be a capable

teacher of her special subjects if a high standard of general education has been attained previous to her training.

Time of Training.—This is usually two years for those who take cookery, laundrywork, and housewifery only. If students take needlework and dress-making in addition, the course generally lasts for three years. Those who take high-class cookery or advanced dressmaking must take an extended course of training.

Scope of Domestic Science Training.—This is increasing, we might almost say, yearly. About ten years ago, in certain schools, teachers of laundrywork were appointed who had received only three months' training. This included not only training in the art of laundrywork but in teaching it. To-day, in the same schools, the teacher of laundrywork is not appointed at the ordinary scale of salary unless she is qualified to teach cookery and housewifery too. This requires a two years' course of training.

The idea is becoming general that we should aim at training the teacher of domestic science rather than the teacher of one section of it (such as laundrywork, or cookery, or dressmaking).

Suggested Scheme of Training.—Such a scheme includes:—

a. *Arts.*—The practical work of cookery, laundrywork, and housewifery (including actual housekeeping and the keeping of real, not imaginary accounts), needlework, and dressmaking.

b. *Science.*—Elementary physical measurement, chemistry, hygiene, physiology, first aid, and sick nursing.

These should have their right place in a course of domestic science. They should be treated as the foundation of the empirical arts. Unless the connection between science and the work done in kitchen and laundry be made an essential part of the scheme of teaching, domestic science loses greatly, whether regarded from the strictly educational or the utilitarian aspect. The domestic science teacher should show her pupils the necessity for understanding the reason for every method they employ, for tracing causes of failure, and for constant efforts to discover better and easier methods of work. The chemical laboratory should be regarded as a place for the working out and elucidation of problems or difficulties met with in the ordinary course of cookery, laundrywork, and housewifery. Scientific training leads to desire to experiment, to questioning of methods in general use, and readiness to adopt new and better ones. It is this attitude of mind which we should encourage in teacher and in pupil. Practical science should include the methods for testing, approving, and valuing the ordinary materials and foodstuffs used in laundry and kitchen. If the training is to include so much science, more time must be given to it than has been possible hitherto. While we are not endeavouring to train physicists or chemists, yet we must realise that domestic economy is really applied physics and chemistry, often of a very high order of complexity. Frequent conferences between domestic science and science teachers are necessary in order that the subjects may be satisfactorily co-ordinated.

Instruction and Practice in Method of Teaching.—1. The elements of psychology, the study of class management, and school organisation.

2. Blackboard drawing and elocution.

3. Actual practice in class teaching.

It is most important that practice in teaching should be gained by teaching pupils from both elementary and secondary schools and also by teaching adults. The more varied the teacher's experience, the more efficiently will she carry on her work. To be successful, a teacher must be adaptable. She cannot be adaptable if she has been trained to teach in one groove; in fact, she can hardly avoid being stereotyped.

Yet the Board of Education regulations as to recognised hours for a cookery diploma insist that the eighty hours of teaching practice which training schools find adequate for this section of the work must all be given in one type of school—

viz., the elementary. It is only possible to give students a wider training if additional hours *beyond* the requisite limit are given. The idea that a teacher will teach any one grade of children better because she has never taught any other grade, seems illogical.

The all-round experience gained by teaching pupils from schools of all types will prove to a student that teaching must be adapted to the needs of those taught.

Additional Aids to the Training of Domestic Science Teachers.—The training schools of domestic science should be conducted on lines similar to those of secondary training colleges. A reading-room and reference library, as well as a common room where students can meet after working hours are over, should be provided. Literary and debating societies and reading clubs should be encouraged among the students.

The specialist teacher of technical subjects loses much by the tendency to underestimate, possibly to ignore, the value of literary interests. Even during the busy years of training it is desirable that the students should be encouraged to take an interest in such things as general literature and the history of the day. These, though having no direct bearing on the work, are necessary as a means of culture.

No apology is needed for introducing this point (though to some it may seem as if it had not much bearing on the question), for many teachers of domestic science lose much by their narrow interests and lack of sympathy with general culture.

9. *The Moral and Economic Standpoint of the Domestic Science Teacher.*
By Miss MAUD TAYLOR.

10. *The Duty of Education Authorities to the Nation respecting the Teaching of Domestic Subjects.* By Mrs. MARGARET ELEANOR PILLOW.

Syllabus.

1. The growing distaste for home life.
2. The shirking of domestic duties by girls, and the desire for outside occupation of any kind not involving domestic responsibilities.
3. The decrease of marriages.
4. The falling birth-rate.
5. Infantile mortality, resulting from ignorance on the part of mothers respecting diet, care of infants, &c.
6. The means for teaching girls domestic subjects (*a*) in the past, (*b*) at present.
7. The definite duty of the education authorities of this country to make provision for teaching the domestic subjects and the management of the home to all the girls in their schools as an essential part of their education.

References were made to the meagre way in which provision is made in many counties—the few isolated lessons yearly; grant-earning a *sine qua non*, &c., and the uneducational and uneconomical aspect of such teaching.

The final point is that neglect of their duty by education authorities throws discredit upon them, and that it lies within their province to do much towards lessening some of the evils referred to in this paper.

The moral effect and the economical outcome to the country at large if education authorities grip their responsibilities and make a determined effort to teach and train girls in domestic subjects on the right lines.

11. *The Problem of Girls' Education in Elementary Schools, with Special Reference to Training for Home Life.* By PROFESSOR MILLICENT MACKENZIE.

1. The education which girls receive in the elementary schools does not seem to prepare them to live the life of the home. Most of them marry and undertake the responsibility of bringing up a family without any real preparation for home-making. In our large towns the majority leave school at fourteen, or even earlier. Too often these girls have worse than no home, and the only training that can influence their later lives must be given in school.

2. The curriculum of the school is usually framed in the interest of the minority, consisting either of those who are able to go on to higher schools, or of those who at least have good home-life to supplement school training. Reading aloud, writing, and arithmetic have little value, as regards character-training, and are too often meaningless arts to girls in the poorer parts of our great cities where people do not read or write, and have no money to invest. Even sewing and cookery as taught (although no doubt of value to those who can practise at home) are quite out of relation to life as they know it.

3. In order really to influence life the school must for these girls combine the functions of home and school. The curriculum must be simplified as regards number of subjects, and only those retained which bear directly on life and character. Health and physical training must be cared for. The school should be so organised right through that it approximates as far as possible to a good home. The little ones, under six or seven, should spend their time in 'the nursery' (instead of the infant school) under the care of educated nurses rather than teachers. Baths, sleep, and play to be of primary importance, and at least one good meal a day prepared by the older girls and partaken of in a decent and orderly manner. The older girls to take it in turns to buy, cook, and serve dinner. Mending and making, washing and cleaning, to be taught practically. Arithmetic, reading, and writing to be subordinate to the study of practical matters and of history, literature, and geography.

4. Experimental schools should be started in which the best ways of carrying out these reforms could be tested.

MONDAY, AUGUST 6.

The following Papers were read:—

1. *The Curriculum of Secondary Schools.*

(i) *By T. E. PAGE, M.A.*

In order to properly adjust the balance of studies in secondary schools, there is a pressing need, not merely for discussion, but for practical action. To that end a strong committee should be immediately formed—and the British Association is in an excellent position to take the initiative—with a view:—

1. to drawing up, at least in outline, a scheme of general study to be pursued, as a preliminary to any special training, by *all* pupils,

(a) In schools which prepare for the Universities, and where pupils stay until the age of eighteen;

(b) In other schools which do not usually prepare for the Universities, and where pupils often leave at the age of sixteen;

2. to indicating, as far as possible, what should be the method and purpose of teaching the various subjects chosen;

3. to determining at what stage, if at any, 'specialisation' should be allowed.

At the present time in the large public schools with which the speaker is especially acquainted the condition of things is somewhat of this nature. Whereas forty or fifty

years ago teaching in such schools was almost wholly classical, circumstances have now wholly altered; but there has been no rational and systematic attempt to deal with a new order of things such as has been created by the immense advance in scientific knowledge and the altered demands of modern life. In fact (i) either the old classical teaching has been retained, and a great variety of other subjects have been added to it in a haphazard manner, with the result that boys are wholly confused by the bewildering number of things they have to learn, so that they learn nothing well, and lose all real mental training; or (ii) classical study has been abandoned altogether by boys who join either an 'Army Class' or a 'Modern Side,' in neither of which does any real educational purpose exist, the former aiming merely at success in examinations, which are continually altering their character according to the changing humour of military authorities; while the latter has usually no higher aims than to give boys what is called a 'practical,' 'useful,' or 'commercial' education, the study of languages, for instance, being conducted chiefly with reference only to their utility, and that of mathematics and science only to their application.

As far as can be judged the tendency is at present to completely oust classical study. The pressure of competition and the obvious commercial value of scientific knowledge make it every day more difficult to maintain a study which has no apparent 'wage-earning' value; and yet in the interest of science as well as literature (using those two words in a wide sense) it is vital that in education no study should be estimated too entirely by the standards of the market or the counting-house. If scientific men allow that type of culture which is represented by classical study to pass into disrepute because it does not 'pay,' they will find that scientific study too will soon be required to stoop to merely commercial aims. But to make such aims supreme is to ruin education, the purpose of which is not merely that a man should be able to earn his bread, but also learn to use his powers wisely and worthily, and which has for its end not only wealth but well-being. Literature and science—again using the terms with the widest meaning—are in fact the two component parts of education (putting aside for the moment such training as is manual or physical), and no form of education is other than maimed which neglects either; and the one object of all schemes of education should be (1) to see that these two studies are properly combined, and (2) that each is so taught as (α) to aid moral and intellectual growth, and (β) to be of actual service in the necessary work of gaining a livelihood. The task is a difficult one, but the problem is in itself clear. It is roughly this: What must we teach in the way of literature, *i.e.*, of all that is meant by culture, art, the humanities, history, or the like, and what in the way of science, *i.e.*, not only of science, but mathematics, geography, &c.? And, secondly, how shall we teach it? Shall we teach language, for instance, chiefly as a mental discipline, as a means of reading with appreciation, or as a convenience in practical life? And so, too, with science and mathematics. Shall mathematics aim at making boys ready-reckoners, and science at teaching them to explain a motor-car, or what? At present all is chaos, and the demand of the market seems likely to become the controlling force unless some body with nobler aims steps in. The British Association is such a body, and its Educational Section has a great opportunity of fulfilling a great duty.

(ii) *By* The Hon. and Rev. E. LYTTLETON, *M.A.*¹

(iii) *By* A. C. BENSON, *M.A.*

For the large majority of average boys, the classical system, however conscientiously administered, is, under present conditions, a deliberate disregarding of most of the methods by which intellectual influences may be brought to bear on the young. The principal defect of public-school education at the present day is its diffuseness, its lack of concentration, its vagueness, its desultoriness. The boys master so little, and so rarely seem to learn how to use their minds. The crying need is *simplification*. By taking out of the ordinary educational scheme, one by

¹ Published in the *School World*, September 1905.

one, all the component parts which are not absolutely essential, and by keeping the balance of subjects carefully in view, it would be possible to arrive at a simple core of education which should be available for all boys, while a little should be added at one point or another, with careful reference to the tastes and abilities of individual boys, by which the emphasis might be laid on one group of subjects rather than on another. It may be objected to this that it would be unpractical. Boys, it may be said, must be educated more or less in the lump, and the school-masters cannot afford to manipulate a boy's idiosyncrasies so delicately.

The scheme is not in the least unpractical, because, though individual characteristics are strongly marked in boys, yet it is very easy to group them on certain fairly broad lines; and if the experiment were tried on a large scale, the numbers would probably not be found to vary seriously.

(1) French, (2) arithmetic, (3) modern history, English and European, with (4) geography, (5) elementary science, taught by popular lectures with demonstrations, (6) Bible teaching, and (7) English should form the central core of education. This would be ample for the majority of average boys. The French should be taught most thoroughly, so that a boy would be able to read it with absolute ease, and write it flexibly and accurately; and the same should apply to the boy's writing of English. The modern history of England and Europe would give the boys an inkling of the development of modern political questions, whereas the custom of doing isolated periods produces nothing but mental confusion. It is so easy to forget that boys do not possess the large, vague, floating stock of hazy general knowledge that men, as a rule, contrive to acquire, which gives an interest to isolated facts, because a dim, general plan of history is lying about in their minds into which details, however loosely, can be fitted. It is, indeed, the absence of imaginative sympathy in the minds of educational theorists with the crude deficiencies of the boyish mind that is responsible for so much mischief. To proceed with the curriculum, the science should be elementary, and largely illustrated by experiments. Experience is against the theory, so dear to certain educationists, that boys are taught accuracy by compelling them to devote their time and energy to work that is irredeemably and essentially dull. This theory only results in contempt and dislike for intellectual processes, which is the rich grain of so much of our educational seed.

Then, according as it is discerned what the boy's special idiosyncrasies are, so should those abilities be catered for. A boy with literary and linguistic tastes might do Latin, Greek, and possibly German; a boy who is linguistic and not literary could do German and be spared Greek; and so on, similarly, with each subject, so that every boy would have a solid centre of necessary work, and as large a margin as possible of work that specially interests him. Of course mistakes would sometimes be made, but they are made on a far more colossal scale now. At Eton, for instance, all the boys are practically specialists in classics. The simplification above suggested, or some similar scheme, is the only practical solution for our present discontent, as the elements of discontent are so very various in character.

With regard to the question of the training of teachers, the time may be anticipated when a teachers' training department will be a normal adjunct to every public school of any importance. The essential thing is not to begin by teaching the young man fresh from the university the theory of the thing; let him make some acquaintance with the practical difficulties and personal problems first, and after a year or two of such discipline a man would be in a position to profit by a six months' course of theory, but not before. Training of teachers may be regarded as an educational factor of high importance, but the training should neither be too protracted nor too scientific.

2. *The Preparatory School Curriculum.* By G. GIDLEY ROBINSON, M.A.

I. *The Preparatory School Curriculum as it is.*—The problem set before it is to satisfy a demand for multiplicity of subjects and for early specialisation as well. This point was fully brought out in the Blue-book on Preparatory Schools

(vol. vi. of Special Reports on Educational Subjects) issued in December 1900. The position is still essentially the same. Preparatory schools, educationally though not locally, are an integral part of the public schools. Hence the preparatory schoolmaster is not a free agent: he is obliged to shape his curriculum according to the requirements of the public schools. These have gradually grown, owing to pressure from without rather than on reasoned grounds of what is best for young boys, and they vary with the different public schools. Scholarships are the root of the mischief, there being keen competition among the public schools to attract clever boys who will afterwards distinguish themselves in classics or mathematics at the University. The needs of scholarship candidates dictate the curriculum for all boys, dull and clever alike. Thus the present curriculum is vitiated by the aim imposed upon it from above, viz., to produce, not the well prepared, but the specialised boy.

II. *General Lines on which Reform is desired by the Association of Preparatory Schools.*—The curriculum should be wide rather than special, and should aim at developing the faculties in due proportion; it should be arranged on principles adapted to the average and not to the exceptional boy. No settlement will be satisfactory which imposes on young boys the rudiments of three languages besides their own; the omission of one language must be an essential principle if discussion is to be fruitful.

III. *The Prospects of Reform* are poor in spite of the closeness of the relations which exist between the preparatory and the public schools, and in spite of the recent appointment of a Joint Committee to consider questions of interest to both, especially the curriculum. The reason for this is the want of agreement among the headmasters of public schools as to general principles of education. This is illustrated by their different requirements in the common entrance examination. And if the headmasters' conference refuses to move, how is reform to be initiated? We need a committee to do for England what the Committee of Ten did for the United States in 1894.

IV. *The Preparatory School Curriculum as it ought to be.*—Supposing early specialisation done away with, what should the curriculum include? There is general agreement as to the necessity of (1) religious and moral training; (2) physical training; (3) practical training of hand and eye. Where disagreement arises is as to (4) literary training. This should include:—

A. *Languages.*—(1) *English*, at present almost crowded out of the curriculum. More and better teaching urgently needed of (a) English composition, both oral and on paper; (b) English literature. We have much to learn from both France and Germany as to methods of teaching the mother tongue.

(2) *French* should be taught from the first. Masters who can speak French fluently and ensure correct pronunciation are very much wanted.

(3) *Latin* has overwhelming claims to inclusion in the curriculum, but should not be begun till the pupil has made real progress in French.

These three languages only should be included in the preparatory school curriculum. Both Greek and German should be deferred till the public school is reached.

B. *History and Geography.*—Both indispensable. The teaching of geography is now better understood; but history teaching needs systematising according to stages.

C. *Mathematics* (Arithmetic, Geometry, Algebra).—The teacher should be trained to explain simple processes in arithmetic.

D. *Nature Study.*—Its claims are being recognised in an increasing number of schools, and the teaching seems to be on right lines, thanks to the Public Schools Science Masters' Association. Enthusiasm rather than any special scientific training is necessary for the teacher.

The development of the teacher himself should be kept steadily in view in training him for his work.

3. *The Waste of Time in Secondary Schools.*

By J. H. LEONARD, B.Sc.

The complaint is frequently heard that the hours in secondary schools are too short for the number of subjects required to be included in the curriculum. In this paper attention is directed to another aspect of this question, viz., the waste of time in secondary school work. Instances are given from actual experience showing how time is wasted (*a*) from over-elaboration of a subject; (*b*) from a lack of co-ordination in the work of related subjects; the latter naturally results in (*c*) the overlapping of subjects. There is, further (*d*) the waste of time in specific subjects as generally taught. It is shown, too, that valuable time is wasted in the rigid adherence to 'term examinations'; and in the preparation for public examinations, the functions of which might be better discharged by adequate inspection. The waste of time entailed by the useless elaboration of marks and reports is also noted.

All such misapplication of school time means loss of energy which might otherwise have been profitably employed. The remedy will, of course, vary in different schools and as regards different subjects. But the principles to be kept in view will be the same throughout: (i) any expenditure of time which does not give adequate return must cease; (ii) subjects included in the curriculum must be co-ordinated.

4. *The Training of Teachers.* By Miss E. CONSTANCE JONES.

Those engaged in training teachers, *i.e.*, the lecturers in training colleges and in the training departments of schools, ought to have the best obtainable preparation for the work—the best school and university education, including, as a very important part of the latter, a genuine and careful study of psychology under competent guidance. They ought also to take a course of training in some existing training college or training department, and, if possible, to have experience of both elementary and secondary training; perhaps, also, of teaching in both elementary and secondary schools (though this may be a counsel of perfection). That they should be of proved ability and special competence for their work, of pleasant manner and sympathetic temper, goes without saying. Further—and this is a point upon which special stress should be laid—it is desirable that the same preparation and qualifications should be required in the lecturers for elementary as for secondary training colleges. Both sorts of colleges want as lecturers men and women whose powers have been brought to the very best they are capable of, whose standard of thought and feeling and action is high, and therefore also sincere and simple; who have truly had 'a liberal education,' and are thus instructed and self-reliant without being inconsiderate or conceited, who see things in right perspective, and though they know the best when they meet it, yet have at the same time a sympathetic understanding of the causes of failure, and can and will help those who stand most in need of encouragement.

The elementary training colleges ought to have such people—that is, they ought to have the best that can be produced—and the secondary can have no better.

If the above suggestion were carried into effect it would probably be very influential indeed in producing better understanding and sympathy between teachers and learners in elementary and secondary schools. In saying this one does not lose sight of the very important differences between elementary and secondary schools, and the kind of teachers and teaching which they require; nor of the relative importance of training and purely intellectual acquirement, according as the teacher has to deal with younger or older, with more instructed or less instructed, pupils; nor should the proposed uniformity of standard for *all* training-college lecturers in the least tend to obscure or confuse any such essential differences.

5. *The Overbalanced Curriculum: a Plea for Individuality in Leisure Hours.* By ARTHUR ROWNTREE, B.A.

1. 'Children should study the elements of a considerable variety of subjects, in order that they may have a chance to determine wisely in what direction their own individual mental powers can be best applied.'

2. 'Training for power of work and service should be the prime object of education throughout life.'

Assuming that we have balanced the curriculum, there still remain, say, twenty hours for leisure-hour pursuits. Until these are dealt with, the curriculum is unstable, overbalanced by the weight of athleticism in one scale, and the consequent lack of ideas in the other.

For inducing the habit of quick and concentrated attention interest is essential. Opportunities must be found in the library, natural history club, archæology society, carpenter's shop, &c.

In a school with seventy years of these traditions boys have recently done excellent work in illustrating the colours of insects, in note-books on microscope work and freshwater shells, including careful drawings of a gnat larva, *Anodonta cygnea*, &c.

Another boy has made a careful study of ecclesiastical architecture in fifteen volumes, including a comparison of three centuries of archiepiscopal vestments from representative tombs.

This work is voluntary, pushed on by the public opinion of parents, the school, and old scholars. Patience, industry, acquisitiveness are fostered; the boy is acting on his own initiative.

That the system helps to solve the problem of the 'duffers' is a small part of its work. It effects moral reform and reduces loafers to a minimum; it widens the circle of thought and tends to a sturdy independence of thought.

It would be an inestimable advantage if some university entrance scholarships were granted as school-leaving scholarships, so that a premium might be placed on the all-roundness engendered by leisure-hour pursuits.

6. *Inspection and Regulation of Schools.* By Rev. E. C. OWEN.

In the first half of the last century secondary schools were mainly controlled by old classical and mathematical universities, and the teaching profession was a branch of the clerical.

From about 1850 a new stage began, and questions of control and curriculum were on the way to be settled on a broader and more national basis. In the same period school teaching differentiated into a separate profession.

The danger ahead, a deterioration in personal qualities of teacher. This shown in two ways:—

(1) The diminution of men of first-rate ability by attraction not only to other professions like the Civil Service, but to administrative posts in education.

(2) Essential that directors, inspectors, &c., should be first-rate men and well paid. But doubtful whether an improvement to substitute inferior teacher well inspected and directed for good teacher uninspected. The man in contact with the pupils' mind ultimately determines result.

(i) Solution not to go back, but forward, viz., to good teacher well inspected and directed.

This not gained by training inferior material. Therefore best material must be attracted. This to be done in two ways: (a) by pay, but financial difficulty; (b) by prospects.

If a certain term of practical experience in schools made a *sine qua non* for administrative posts, those gain, and a motive added to attract into education.

(ii) Initiative of teachers hampered by organisation.

This not a serious danger to assistant masters if requirements of Board of

Education and local authorities can be coordinated with requirements of examining bodies. But present strain on headmasters very great. Time and energy taken up on organisation of details which better spent on teaching or personal control.

Solutions (a) to relieve them by appointment of an official within school, charged with the task; but (1) additional expense on non-productive labour; (2) ultimately all matters must be determined by headmaster. Special strain on poor schools.

(b) To substitute general for special control.

Present system of control in secondary schools imitated from system in elementary schools. Required more laxity in adjustment, e.g., a school to receive general reorganisation, subject to, say, triennial inspection and occasional visits from local inspector, without regulations of time for each subject, &c.

Promotion at present administrative, i.e., to headmastership, not to the teacher *qua* teacher. Desideratum, a career within the profession for the teacher without the need of administrative work.

7. *Scientific Method in the Study of School Teaching.*

By Professor J. J. FINDLAY, Ph.D.

Progress in the study of education has been hindered:—

(1) By the error made by the earlier advocates of 'training' in treating the study of education as a kind of applied philosophy; the work of eminent psychologists such as Professor James Ward and Professors James and Dewey in America has, however, served to clear this issue. It is now recognised that the chief service to be rendered from that quarter is in utilising the results of experimental psychology, and especially of genetic psychology. The latter, in its more popular form of child-study, is already producing definite results in school practice.

Apart from psychology, the relation of the philosophical disciplines (logic, ethics, æsthetics) to education is similar to that presented in other social sciences, and its value to the teacher is neither less nor greater than its value to all educated men engaged in professions which deal with human affairs.

(2) By the popular interest in education and in schools. Everybody has a direct interest both in the political and personal aspects of the subject, and readily adopts an opinion on many topics embraced under the term. Hence the necessity for such prolonged investigation as is demanded by other branches of science has been commonly denied—equally by men of letters and science as by the general public.

(3) By the extensive range of studies included under 'education.' Thus the only topics so far handled in a scientific method by this Section are those concerned with the public administration and organisation of education. In these fields the method is similar to that pursued in economics or politics. But in school teaching the method must be different. Results can only be secured from the observation of children *while actually acquiring school experience.*

(4) By the peculiar difficulties to which such prolonged investigation of children is subject (difficulties which in part account for the reluctance with which both teachers and public authorities welcome any 'reform' in school procedure). The achievement of any new 'result' in school teaching requires the co-operation of several teachers with children placed in their hands for several years, the whole process being conducted with persistence and continuity. From every quarter 'interference' with the experiment while in process has to be anticipated. Equally difficult is it to secure a reliable judgment upon the nature of the result when the work has been accomplished.

II. Hence some of the important reforms introduced into English schools (e.g., in manual training, modern language teaching, practical mathematics) have been due, not to investigations conducted within the schools on a scientific method, but to movements outside the schools, which have first of all gained the public ear, and have then been adopted without an adequate inquiry into

children's nature or needs. Thus these reforms have largely gone to waste, and in proportion to the public interest excited have produced only a slight effect upon the young.

This outside pressure upon the work of the schools will always be powerful; but it should also be the task of those who study school teaching to examine new proposals experimentally, and to direct the current so as really to serve the needs of children.

III. Other reforms, however, have been produced with a greater approach to scientific method—*i.e.*, they have been prefaced with a definite theory as regards both the ideal to be achieved and the nature of the scholar who is to undergo the experience—followed by a definite experiment in applying theory to practice over an extended period. In England the work of Arnold of Rugby approached this character, and also that of William Ellis in the Birkbeck Schools. In Germany the work of Herbart and his followers has been associated (not without great opposition) with the Universities, and has created a definite group of teachers professing adherence to 'Wissenschaftliche Pädagogik.' In America there are many examples: the influence of Professor Dewey in his Experimental School (University of Chicago) is perhaps the most conspicuous.

IV. Conditions under which such prolonged experiment can be conducted with prospect of success: (a) There must be assumed a fairly comprehensive theory, both of the ideal to be achieved and the processes by which the scholars' experience should develop during the years of school. (b) A staff of teachers in sympathy with this theory and prepared to co-operate in executing the plan over a period of years. (c) A sufficient number of scholars in small classes who may be expected to remain under observation and teaching during one well-defined period of school life. (There is usually no difficulty found in securing all the scholars that are needed.) (d) Time available for keeping records of the processes adopted (syllabuses, notes of lessons, &c.), and records also of the mental and physical progress of each scholar. In order that the work should be of service the observation of the scholar's life should be complete, and should take special cognisance of those physical conditions which medical men can now investigate with thoroughness.

V. Effect produced upon teachers and students of education who work in such a 'laboratory.' The habit of treating problems of teaching in a scientific spirit, instead of relegating such problems to the region of prejudice and tradition is in itself a most important effect. Such a habit is not easily acquired. It by no means follows that men who are scientifically trained in one branch of science will transfer the habit to their treatment of educational science. There is little warrant for the belief in the existence of generalised habits of this kind. Apart from this students secure a detailed knowledge of the reactions of school experience upon the life of individual scholars such as can scarcely be secured otherwise.

VI. Effect upon the theoretical exposition of education by professors and lecturers when their work is associated with a school which they direct; speculations as to cause and effect are thus limited by educational results.

VII. The plan proposed in the Demonstration Schools at Manchester to investigate school teaching on such lines. The following topics have so far received special attention: Elementary teaching of modern languages,¹ of practical mathematics, and of literature; association of parents with school life; experiment with a school 'camp'; (transferring town scholars with their teachers for teaching and training during a short period to the country).

VIII. Prospect of recognition and support for such 'laboratory' work by Universities and by public authorities.

¹ A report by Professor Findlay on Investigations into Modern Language Teaching is offered in another paper.

TUESDAY, AUGUST 7.

The following Papers were read:—

1. *The Inspection and Examination of Schools.*¹
By Professor H. E. ARMSTRONG, F.R.S.

2. *The Constructive Work of an Inspector of Schools.*
By W. MAYHOWE HELLER, B.Sc.

The transition from a system of payment by results on individual examination to a system of inspection was certainly accompanied for some years, both in English and Irish schools, by a diminution in the proficiency of the pupils in those subjects which had been most severely examined and most mechanically taught under the older system.

Parents noticed a want of power of application and concentration in their children, and masters of secondary and technical schools receiving pupils from the primary schools discovered that the mesh of the inspection net was not sufficiently fine to guarantee the standard of proficiency prescribed by the Code.

Among parents there is still a good deal of scepticism as to the efficacy of inspection, and not a few of the older teachers would welcome a return to a system in which the Procrustean test of examination provided them with a definite standard of efficiency.

It would indeed be an educational calamity to revert to the system of Chinese slavery of the days of 'payment by results,' and to avoid this danger it is essential that inspection shall guarantee both efficiency of instruction and general proficiency of the pupils.

The fundamental functions of the inspector of schools are:—

(a) To see that value is obtained for the money spent on the educational work of schools.

(b) To suggest remedies where due educational economy is not practised.

Although the education authority (either local or central) is responsible for the educational policy of the schools, it must look for advice to its experts, the inspectors, who, better than others, can appreciate the educational needs of a district, and are in a unique position to evaluate the results of the various programmes and methods followed in the schools under their charge.

Whether an official of the local or central authority, the inspector is the servant of that authority; both he and the teacher receive common instructions from it. The first condition of efficiency is, therefore, that these instructions are wise, clear, and definite, and that they are loyally observed by teacher and inspector alike.

Under the 'results system' the duties of the inspector mainly consisted in testing the individual proficiency of pupils in a very restricted programme, and as the system developed in intensity he became more and more an examining machine; but with the change to more rational methods of allocating grants for education and testing the efficiency of teachers the functions of the inspector underwent at once a complete change. He was now more concerned with the work of the teacher than that of the pupils, and was called upon to act as the guide, philosopher, and friend of the former. If he found that a school was well organised; that the time-table was observed and showed a proper balance of subjects to provide the necessary types of training; that the teachers were doing the work best suited to their abilities and experience; that definite and well-considered schemes of instruction were drawn up in advance for the year's work; that the teaching received adequate preparation; that the tone of pupils was good

¹ Published in the *School World*, September 1906.

that the latter were to a reasonable extent interested in their work; that they exhibited an increasing intelligence and executive ability from year to year—then, if all these conditions were fulfilled, he was in a position to say that public money was not misspent and that the best was being done for the children.

Can a greater change in the lifework of a man be imagined than was necessitated by the change in system in the work of an inspector? The duties inspectors were called upon to exercise under the old system could have been satisfactorily performed by men of far less academic distinction and less liberal remuneration. Many a brilliant man was lost to education by the deadly mechanical monotony of the useless individual examination of huge numbers of children day after day. It is not surprising that inspection work became to some merely a means of livelihood, while the best intellectual energies were devoted to problems outside those of education. What wonder that some never succeeded in grasping the fundamental aims and methods of school work? But though the tendencies of the results system justify these remarks, it must be said at once that a much larger number of both teachers and inspectors than it was reasonable to expect under the circumstances realised the proper functions of schools and teachers and saw through the iniquities of the system. The point to bear in mind is that the change of system placed suddenly upon the shoulders of the inspectorate duties and responsibilities for which their previous training was by no means the best suited.

The development of School Boards, especially in the great urban centres, did much to create a public opinion and interest in education. These authorities realised that the Government examiner could and did do little to raise the standards of educational ideals and efficiency. The great progress in methods of instruction and the many valuable educational experiments of the last twenty-five years, which compare very favourably with the achievements during the same period in any other country, were due to the enterprise of the great School Boards and the constructive work of their inspectors and organisers, who were in constant touch with the work of the schools and on terms of closer intimacy and sympathy with the teachers than the Government inspectors could be. These constructive inspectors of the local authorities realised that no material progress could be made unless much was done to supplement the work of the training colleges. The Government inspector in many cases co-operated enthusiastically with the local inspectors and organisers, to the great advantage of the schools.

Method of Appointment.—Two methods of appointing inspectors have in the past existed:—

1. Selection by open competitive examination;
2. Election by the central educational authority.

The first method, which is now probably extinct, would appear to be a very uncertain method of securing the right men, but under the results system it was probably as good as any other. It did at least secure men of wider knowledge and culture than the majority of those whose work they were called upon to inspect. But a written competitive examination, ignoring both the previous career and experience of the candidate, as well as his personal qualities (except with regard to physical fitness), cannot be regarded as a satisfactory means of selecting men who will be required to indicate the best methods of instruction and organisation, and to hold up before the teacher the highest possible ideals in the formation of the habits and character of a large fraction of the nation.

It is evidently necessary to fall back upon the method of election by a competent body of men who may be trusted to exercise honesty and sound judgment in selecting those best fitted for the great responsibilities of the work of inspection.

There is some difference of opinion as to the necessity of an inspector possessing teaching experience. But how can an inspector, without a varied teaching experience, and that experience of the right kind, presume to criticise the methods of others? The teacher is unlikely to respect or to act upon the suggestions of an inspector who has only a theoretical knowledge of education. The position of such an inspector is like that of the student in the practical examination who,

having repeatedly failed to perform an experiment, thought he ought to receive marks for 'knowing how to do it.'

Assuming, then, that the inspector should possess successful teaching experience, he cannot be appointed at so early an age as hitherto. He should have experience of both primary and secondary schools, and should, if possible, have gained that wider outlook on school work and organisation which comes only with the responsibilities of headmastership. He must realise that education is an experimental science, and that scientific method underlies the whole art of teaching. He should be an enthusiastic student of educational progress in other countries than his own, and be possessed of the personal qualities of tact, sympathy, and firmness.

Influence of the Inspector.—Under the existing system in England the influence of the inspector of the local authority is probably greater than that of the Government inspector. In Ireland, the Government inspector combines both functions, and so absolute is his influence that the efficiency of schools is almost a measure of the efficiency of inspection. Expressed generally, what the inspector requires will be done, but what he does not ask for will not be attempted.

In the primary school it is often desirable to have every subject dealt with by the same inspector; he must, therefore, have a thorough acquaintance with the matter of and method of teaching all the principal subjects of the curriculum. If he is only slightly acquainted with some branch, he is almost certain to ignore it, and by so doing will in a very short time destroy any effective teaching of that branch. It is not to be expected that teachers will put themselves to considerable trouble in preparing and teaching a subject if the results of their work are neither asked for nor commented upon.

This does not mean that the inspector should be a 'Jack of all trades and master of none,' but he should at least be thoroughly familiar with the aims and methods underlying the teaching of all subjects. It is very desirable that he shall have reached a high academic standard in one or more branches. In the secondary school, it is not reasonable to expect one man to inspect constructively the teaching of all subjects; at least two types are necessary: a literary man with a knowledge of classics, English, and foreign languages, and a scientific and practically trained man, with a knowledge of mathematics, science, manual instruction, drawing, geography, and, if necessary, domestic science and drawing.

The time seems to have arrived when the term *inspector* may be usefully abolished. Teachers need more than inspection, criticism, and censure; they need suggestion, help, and encouragement as well. The 'inspector' would spend his day watching the teachers at work (under highly artificial conditions), would say little or nothing, go home, and write his report, giving praise or censure as the case may be; he would probably only have seen specimens of work in less than half the subjects of the school programme, and the lessons he listened to had probably been given to the same pupils before, and were, therefore, worthless as specimens of teaching. If we cannot change the title, let us think of inspectors as *school advisers*, who are slow to censure unless suggestions have been ignored and regulations infringed.

In nine cases out of ten a lesson given before the inspector is of no value as a test of teaching ability; neither teacher nor pupils are in a normal condition. The inspector can learn far more if he asks the teacher to question a class on a recent lesson, or, still better, if he questions the class himself; if he knows his business he will soon discover the manner in which the subject was presented.

At the same time, in his desire to remain on friendly terms with the teacher, the inspector must not pass by unnoticed matters of organisation and method that need reform. Some of the American schools, especially in the smaller cities, are good examples of what a complete absence of inspection or external criticism may lead to; with an environment of progress the schools are stagnant.

It is sometimes said to be undignified for an inspector to teach; the reply is that a good inspector cannot help teaching—it is his only method of getting into intellectual touch with a class. The inspector is, after all, the educational doctor of the school. He calls in a specialist when the case is outside his own experience;

he should always adopt a cheerful bedside manner, but he must see that his prescriptions are carefully compounded, and that his orders are faithfully carried out; before he prescribes he must discover *why* the patient is sick.

The School Report.—The inspector is often placed in a serious quandary when writing his report. If it is constructive, as it should be, the school committee or governors are apt to mistake suggestion for censure, and often form very unjust opinions of the teaching staff. Even if the committee understands the report, the parents often do not, and it is doubtful whether the publication of such reports is desirable.

The frequent changes of inspectors in a given district has a very disturbing effect on the work of the schools. It takes a considerable time to know a large number of schools and teachers, and first impressions are sometimes wrong. An inspector must be left for several years in the same district before his constructive work can bear fruit.

Uniformity of Inspection Standards.—One of the chief charges brought by teachers against the present inspection system is the want of uniformity in inspection standards. What passes for 'good' with one inspector is only 'fair' with another. The remedy lies with the chief inspectors. They should see that the instructions to inspectors (which are the common property of teachers and inspectors) are clear, definite, and sufficient, and that these are strictly observed. More frequent conferences among inspectors, and a loyalty to the decision of the majority, are desirable; there are very few questions on which real disagreement is possible.

In conclusion, it may be pointed out that the inspector has a magnificent field for scientific research around him. He can watch, foster, and institute educational experiments of all kinds; and by encouraging teachers to meet together to discuss the details, aims, and methods of their professional work, in which he should show keen interest himself, he can secure educational progress in his sphere of influence.

3. *Processes involved in the Acquirement of a Foreign Language.*

By Professor J. J. FINDLAY.

1. The investigations which the author undertook commenced in 1891 (after the visit of Professors Passy and Vietor to England) and have been continued under varying conditions up to the present. The specific problem presented for discussion is the mental processes at work in acquiring a foreign language (leaving on one side the ultimate aims presupposed by a teacher).

2. The author observed and noted (*a*) his own experiences; (*b*) those of fellow-students when acquiring a foreign tongue; (*c*) children and students in small classes, sometimes taught 'intensively,' (*d*) classes in a school in Cardiff, 1898-1903, in which he was able, with exceptional freedom, to direct a co-ordinated scheme of teaching, extending over five years; the classes were taught by a number of able assistant masters, who co-operated on common principles of teaching: the results were annually examined in detail by the Central Welsh Board (younger scholars orally, older scholars also in writing for junior and senior certificates); these reports are available for reference.

3. The important phenomena may be summarised thus:—(1) The process is fundamentally one of acquiring habits of automatic reaction in the association of foreign symbols with ideas. (2) Distinctions between reading and hearing, speaking and writing are of minor importance. (3) The employment of language (native or foreign) is a synthetic, not an analytic process; the recognition of the single symbol is merely a step (and often an unnecessary step) towards the immediate recognition of the general sense of a passage. But an equivalent in the vernacular may often be suggested for a moment and then encouraged to sink below the threshold of consciousness. (4) In contrast to other arts (compare *e.g.*, golf) the special hindrance encountered in acquiring a second language is due to the extraordinary resistance of the native speech 'centre.' (5) Hence to the beginner the path of least discomfort is to interpret the foreign symbol *through* the native

symbol, and thus to set up a translation habit, which is really a bar to progress, since objects of thought can only be symbolised with effect when the objective, the thought, is *directly* expressed by the symbol appropriate to it. (6) When once the establishment (mental and physical) of a new speech centre is begun, *with its accompanying set of experiences*, the force of resistance rapidly diminishes. (7) The rate of progress depends (a) upon the intensity of the learner's absorption in the new art during the early stage; (b) upon suitable environment with appropriate objects of thought. (8) When the new habit is established in only a small degree, traces abide for a great length of time *and can be easily recovered*. (9) A month's residence among foreign people or a year's course of school instruction suffices to overcome the resistance in its earliest and strongest stage. (10) The use of a special phonetic script is of doubtful value to learners, except to adults who have received a philological training. (11) The study of changes in nervous function accompanying the mental process are not at present adequate to confirm these conclusions, but inquiry into cases of aphasia among bilingual people may be expected to throw some light upon the nature of brain centres for foreign speech. (12) The attempt to 'establish' two foreign languages at the same time should not be made; each tends to inhibit the other. French, *e.g.*, should hold the field for three years at least before German or Spanish is introduced. Latin, however, taken on a translation method, does not appreciably interfere.

4. New factors presented when classes of twenty-five to thirty-five are taught together. (1) A body of teachers are needed who can be relied upon to carry through the experiment over several years.¹ (2) The general efficiency of the school life and teaching *in other departments* affects vitally the issue in success or failure. (3) Detailed preparation for each portion of the work by the teacher is essential; teachers can seldom find time for such preparation when in full practice. (4) Progress is hindered by the incapacity of some scholars to apperceive new sounds; on the other hand, the stimulus of numbers (here as in all branches of teaching) aids progress.

5. In order to carry through an extended piece of work of this kind, the teachers concerned need to come to some agreement as to the working of cause and effect in mental development; so long as 'direct' methods of teaching are regarded as leading to enfeeblement of mind, it is unlikely that analytic methods will be discarded. This applies still more to the methods adopted by examiners and inspectors.

6. This paper is submitted as an example of the way in which problems in school teaching may be fruitfully investigated. It is obvious that no finality in quantitative results can be recorded such as are forthcoming in more familiar fields of scientific investigation. But it is submitted that it would be feasible, by adequate inquiry (with a check upon varying data and conditions), to secure records vouched for by competent authorities which would help to solve some controversies. But such investigations must extend over a period of years, and the 'results' must be sought in the positive attainments of the scholars at the close of the period.

A number of such reports have been published in Germany during the last twenty years, but it seemed best for the present purpose to confine this report to personal experience. The standpoint as to mental process is elucidated with great skill in 'Der psychologische Zusammenhang in der Didaktik der neusprachlichen Unterrichts,' von Dr. B. Eggert (Berlin, Reuther u. und Reichard, 1904).

[The author is now repeating this experiment (using the German language) in the Fielden Demonstration School referred to in another paper, but the results, under the special conditions of that school, are not likely to render the same service as those secured at Cardiff.]

¹ The author expressed his indebtedness to his colleagues who had charge of the French teaching in this school. Most of the success of the prolonged experiment at Cardiff must be attributed to them.

4. *On the Cultivation of Literary Taste.* By Miss LUCY HARRISON.5. *The Position of German in the Educational Curriculum.*
By Professor J. G. ROBERTSON.

Decline of German as a school-subject in England in recent years. Statistics. The position of German in the British Universities. Comparison with America, where the opposite phenomenon is to be observed, German having in the course of the last ten or twenty years advanced rapidly in favour there. The practical utility of the subject, owing to various reasons, not recognised, or at least underestimated, in England. Effects of political differences and commercial rivalry. A deeper reason in the estrangement between German and English intellectual life in the present generation. Comparison of the interest in German poetry and philosophy in the first half of the nineteenth century (Carlyle to Matthew Arnold) with the ignorance and indifference to be met with in intellectual circles at the present day. This attitude of mind reflected in the teaching at the Universities, where Goethe twenty or thirty years ago was by no means a negligible force, and is now rarely even read. In turn, this indifference influences the position of German in the schools and the character of the teaching.

Suggested remedies. Vitalising the methods of teaching German. Methods of approaching the literature. The particular educational value of German literature as an instrument of culture. The importance of German depends, as American educational leaders have recognised, not merely on the utility of the language as a tool for the student of science or philosophy, but as a means of bringing us into touch with a literature invaluable for the development of the Anglo-Saxon mind: it introduces us to a criticism of life and an attitude towards art and literature which is of supreme value as a corrective to the more sternly practical ideals of the English and American peoples. Effects of the attention given to German already noticeable in American education. The necessity of a reconsideration of the position of German in English education from a similar point of view.

6. *The Teaching of Mechanics by Experiment.*¹ By C. E. ASHFORD, M.A.

¹ Published in the *School World*, September 1906.

APPENDIX.

SOUTH AFRICA MEDAL FUND.

A LIST of contributions, promised or received, was published in the Annual Report for 1905. Of these, sums amounting to 2*l.* 1*s.* remained unpaid at the close of the Account on January 8, 1907, and are therefore deducted from the published total of 858*l.* 19*s.* 6*d.*

The following additional contributions to the Fund have been made:—

	<i>£</i>	<i>s.</i>	<i>d.</i>
Mrs. Hopkinson (second donation)	50	0	0
Mr. S. Vaughan Morgan	3	3	0

Account of the South Africa Medal Fund.

<i>Receipts.</i>		<i>Expenditure.</i>	
<i>£</i>	<i>s.</i>	<i>£</i>	<i>s.</i>
<i>d.</i>	<i>d.</i>	<i>d.</i>	<i>d.</i>
Contributions from Members	910	1	6
Transferred from Special South Africa Fund	584	17	6
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TO THE PRESIDENT OF THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, CAPE TOWN, SOUTH AFRICA.

British Association for the Advancement of Science, November 9, 1906.

SIR,—I beg leave to inform you that the Council of the British Association, at its Meeting on November 2, formally approved of the appointments made by your Association of the undermentioned representatives, to act in their official capacity, as Trustees of the South Africa Medal Fund, namely: The Superintendent-General of Education for Cape Colony; the Controller and Auditor-General for Cape Colony; the Registrar of the University of the Cape of Good Hope.

The following Resolution was unanimously adopted by the Council:—

‘(1) That, in accordance with the wishes of the subscribers, the South Africa Medal Fund be invested in the names of the Trustees appointed by the South African Association for the Advancement of Science; and (2) that the dies for the Medal be transferred to the Association, to which, in its corporate capacity, the administration of the Fund and the award of the Medal shall be, and are hereby, entrusted, under the conditions specified in the Report of the Medal Committee.’

The terms of conveyance are contained in the Report of the Medal Committee, and are as follows:—

I. That the Fund be devoted to the preparation of a die for a Medal to be struck in bronze, $2\frac{1}{2}$ inches in diameter; and that the balance be invested and the annual income held in trust.

II. That the Medal and income of the Fund be awarded by the South African Association for the Advancement of Science *for achievement and promise in scientific research in South Africa*.

III. That, so far as circumstances admit, the award be made annually.

At a Meeting of the Council of the British Association held in London on November 2, a question was asked as to whether or no the award was necessarily to be made annually. It is possible that some Members of your body may raise the same question; and therefore I venture to point out that, under the third of these Resolutions, the South African Association has full liberty to suspend the award of the Medal and of the sum of money in aid of research in any years in which no suitable candidate is forthcoming.

I am, Sir, yours faithfully,

(signed)

G. H. DARWIN,
Chairman of the Medal Fund.

Reply.

The South African Association for the Advancement of Science,
December, 1906.

SIR,—I have to acknowledge the receipt of your letter of the 9th ult. informing me that the Council of the British Association has approved of the appointments made by this Association in connection with the South Africa Medal Fund, and that, in accordance with the wishes of the subscribers, the Fund is being invested in the names of the Trustees appointed by this Association.

I further observe that the dies for the Medal are being transferred to this Association, and note the terms of conveyance as contained in the Report of the Medal Committee.

I have to state that the Trustees of the Medal Fund have been advised of their formal appointment, and have been requested to decide in what manner the Fund is to be invested.

A Committee has also been appointed to draft provisional rules as to the

conditions on which the Medal will be awarded, which will be referred for the consideration of your Council before being finally adopted.

I trust this will meet with your approval.

I am, Sir, yours faithfully,
(signed) JAMES HYSLOP,
President, S. A. Association for the Advancement of Science.

Sir G. H. DARWIN,
Chairman, South Africa Medal Fund,
British Association for the Advancement of Science,
Burlington House, London.

TO THE GENERAL TREASURER OF THE SOUTH AFRICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE, P.O. BOX 1497, CAPE TOWN.

British Association for the Advancement of Science,
Burlington House, London: January 18, 1907.

DEAR SIR,—I have the pleasure to enclose herewith the audited account of our South Africa Medal Fund, together with a draft on the Standard Bank for the balance of the Fund, amounting to 1,376*l.* We shall be glad to receive an acknowledgment.

I have written to the President of your Association by this mail, sending him a duplicate or second draft for 1,376*l.*, which would be available in the event of this letter miscarrying.

I am, dear Sir, yours faithfully,
(signed) A. SILVA WHITE.
Assistant Secretary.

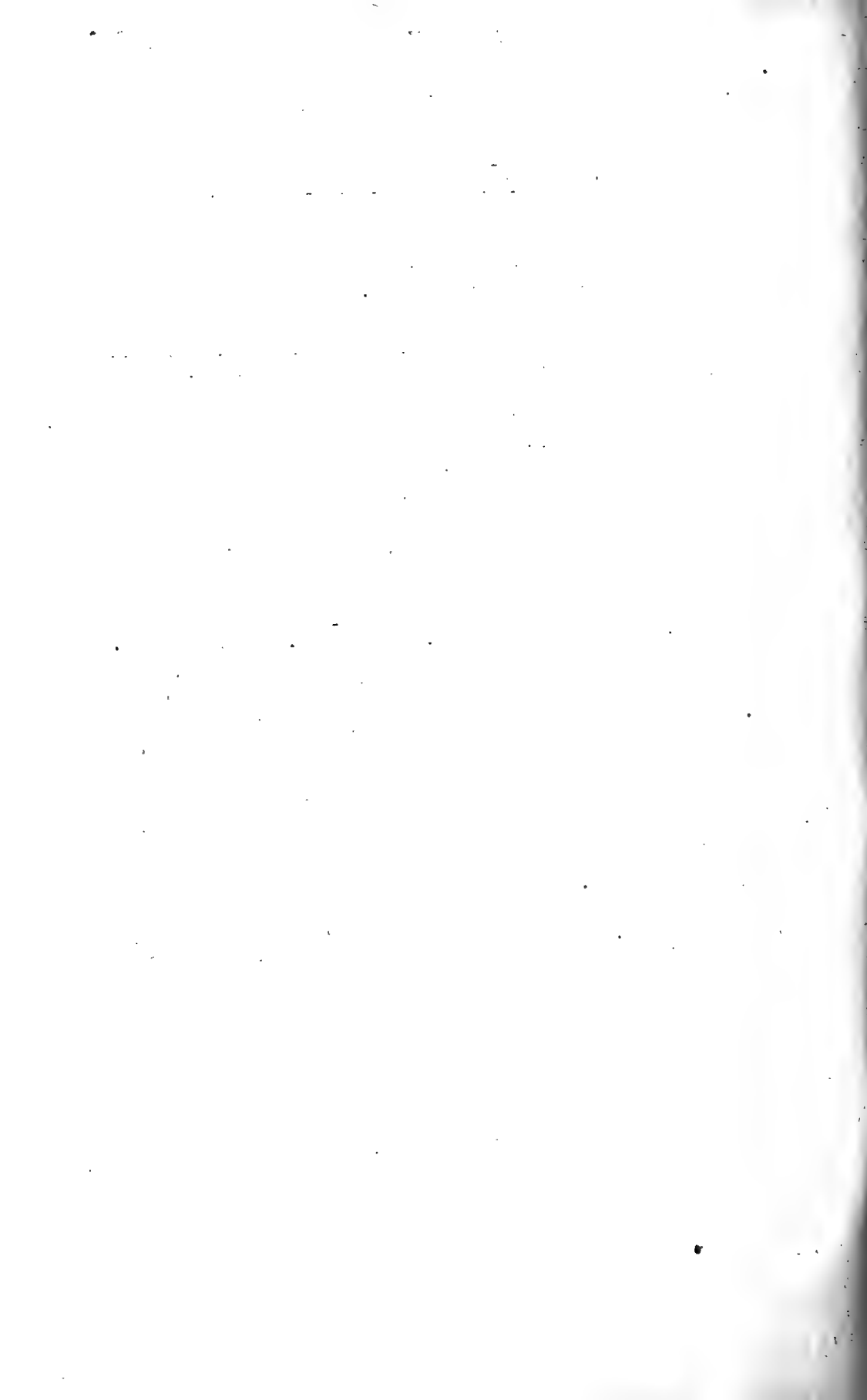
TO THE ASSISTANT SECRETARY, BRITISH ASSOCIATION, LONDON.

South African Association for the Advancement of Science,
Cape Town, February 9, 1907.

DEAR SIR,—I am directed to acknowledge, on behalf of the General Treasurer, the receipt of your letter of the 18th ultimo enclosing a draft, on account of the South Africa Medal Fund, amounting to 1,376*l.* This sum has been duly handed over to the Trustees of the Fund.

Your letter with the audited account of the Fund will be submitted to the Council at its next meeting.

I am, dear Sir, yours faithfully,
(signed) E. HOPE JONES,
Assistant General Secretary for Cape Colony and Rhodesia.



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*An asterisk * indicates that the title only of the communication is given.*

The mark † indicates the same, but that a reference is given to the Journal or News paper where the paper is published in extenso.

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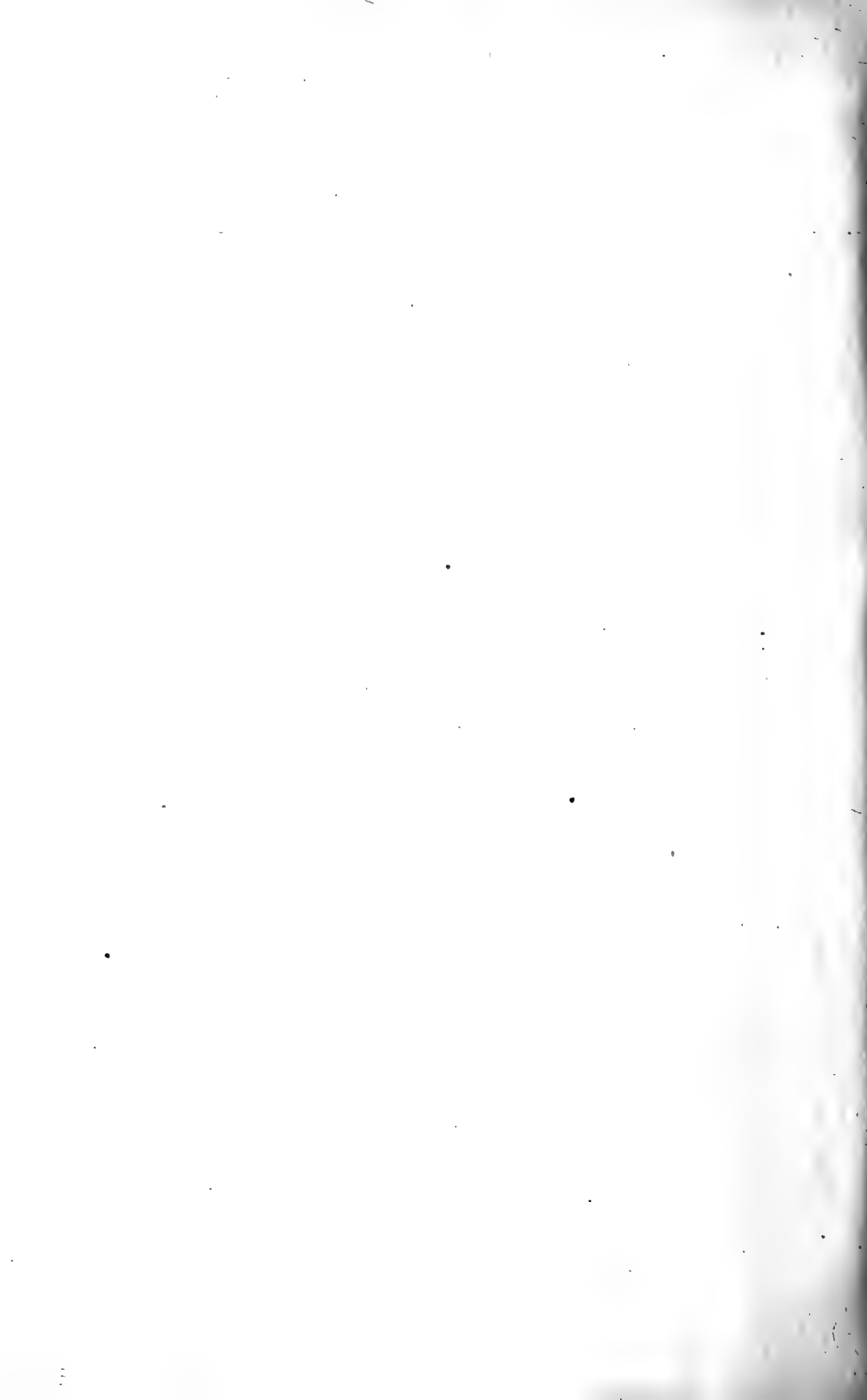
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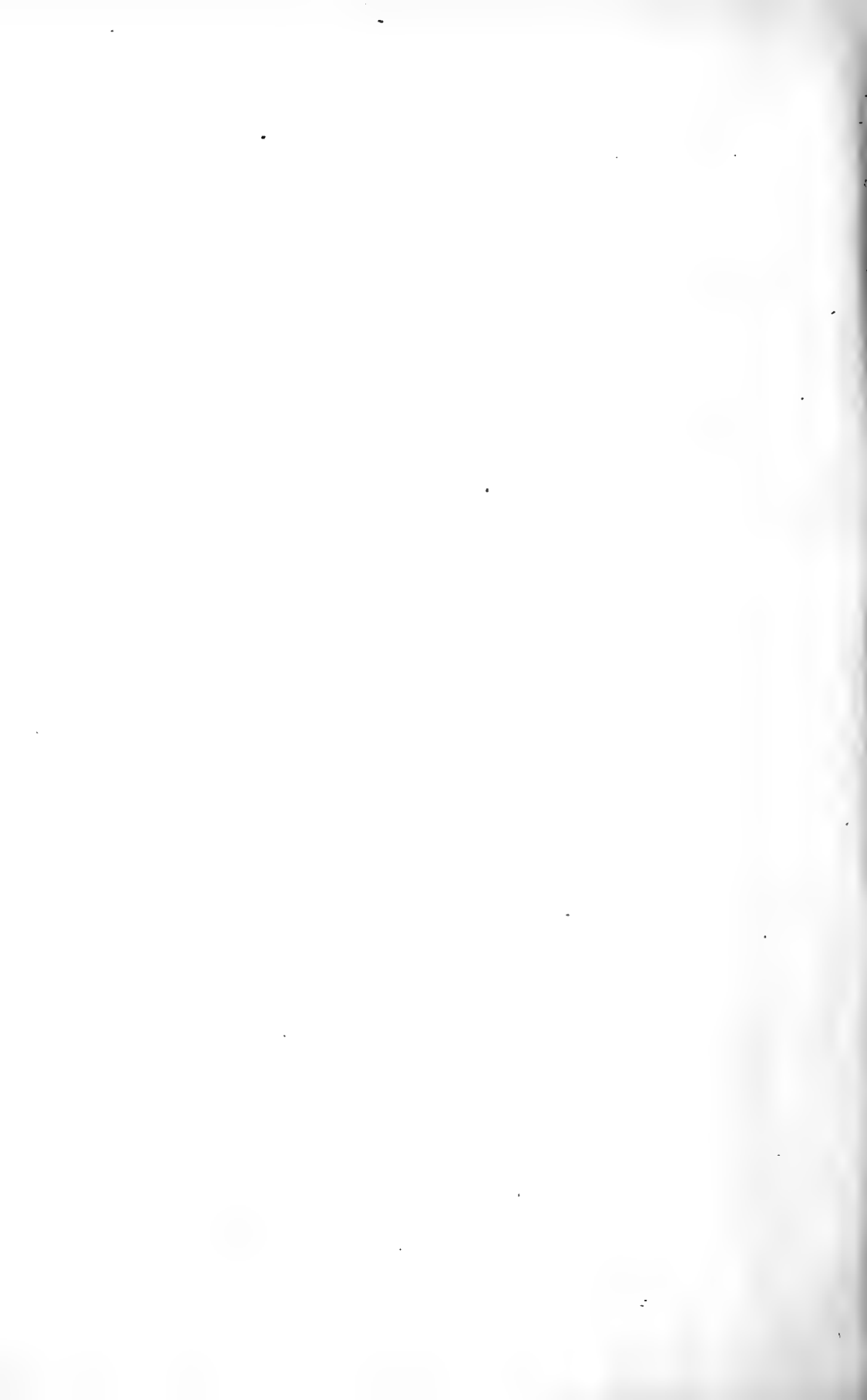
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Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

*Notice of changes of residence should be sent to the Assistant Secretary,
Burlington House, W.*

Year of
Election.

1905. *à Ababrelton, Robert A. P.O. Box 322, Pietermaritzburg, Natal.
1887. *ABBE, Professor CLEVELAND. Weather Bureau, Department of Agriculture, Washington, U.S.A.
1898. §Abbott, George, M.R.C.S., F.G.S. 33 Upper Grosvenor-road, Tunbridge Wells.
1881. *Abbott, R. T. G. Whitley House, Malton.
1885. *ABERDEEN, The Earl of, G.C.M.G., LL.D. Haddo House, Aberdeen.
1885. ‡Aberdeen, The Countess of. Haddo House, Aberdeen.
1873. *ABNEY, Captain Sir W. DE W., K.C.B., D.C.L., F.R.S., F.R.A.S. (Pres. A, 1889; Pres. L, 1903; Council, 1884-89, 1902-05, 1906-) Measham Hall, Leicestershire.
1905. ‡Abrahamson, Louis. Civil Service Club, Cape Town.
1905. §Aburrow, Charles. P.O. Box 534, Johannesburg.
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. Walwood, Banstead, Surrey.
1894. *Acland, Henry Dyke, F.G.S. Lamorva, Falmouth.
1877. *Acland, Theodore Dyke, M.D. 19 Bryanston-square, W.

Year of
Election.

1904. §Acton, T. A. 3 Grove-road, Wrexham.
 1898. †Acworth, W. M. The Albany, W.
 1901. †Adam, J. Miller. 15 Walmer-crescent, Glasgow.
 1887. †ADAMI, J. G., M.A., M.D., F.R.S., Professor of Pathology in McGill University, Montreal, Canada.
 1901. §Adams, John, M.A., Professor of Education in the University of London. 23 Tanza-road, Hampstead, N.W.
 1871. †Adams, John R. 2 Nutley-terrace, Hampstead, N.W.
 1904. †Adams, W. G. S., M.A. Department of Agriculture, Upper Merrion-street, Dublin.
 1869. *ADAMS, WILLIAM GRYLLES, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S. (Pres. A, 1880; Council, 1878-85). 1 Fortfield-terrace, Sidmouth.
 1901. †Adamson, P. 11 Fairlie Park-drive, Glasgow.
 1898. †Addison, William L. T. Byng Inlet, Ontario, Canada.
 1890. †ADENEY, W. E., D.Sc., F.C.S. Royal University of Ireland, Earlsfort-terrace, Dublin.
 1899. *Adie, R. H., M.A., B.Sc. 136 Huntingdon-road, Cambridge.
 1905. †Ade, Henry. P.O. Box 1059, Johannesburg.
 1902. †Agnew, Samuel, M.D. Bengal-place, Lurgan.
 1906. §Aikman, J. A. 6 Glencairn-crescent, Edinburgh.
 1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
 1895. *Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.
 1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
 1871. §AITKEN, JOHN, LL.D., F.R.S., F.R.S.E. Ardenlea, Falkirk, N.B.
 1901. §Aitken, Thomas, M.Inst.C.E. County Buildings, Cupar-Fife.
 1884. *Alabaster, H. Milton, Grange-road, Sutton, Surrey.
 1886. *Albright, G. S. Broomesberrow Place, Ledbury.
 1905. †Albright, Miss. Finstal Farm, Finstal, Bromsgrove, Worcester-shire.
 1900. *Aldren, Francis J., M.A. The Lizans, Malvern Link.
 1896. §Aldridge, J. G. W., Assoc.M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
 1905. *Alexander, J. Abercromby. 46 Clarendon-road, Bedford.
 1888. *Alexander, Patrick Y. Rothesay, Spencer-road, Southsea, Hants.
 1891. *Alford, Charles J., F.G.S. 15 Great St. Helens, E.C.
 1883. †Alger, W. H. The Manor House, Stoke Damerel, South Devon.
 1883. †Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
 1901. *Allan, James A. Westerton, Milngavie.
 1904. *Allcock, William Burt. Emmanuel College, Cambridge.
 1879. *Allen, Rev. A. J. C. 34 Lensfield-road, Cambridge.
 1898. §ALLEN, Dr. E. J. The Laboratory, Citadel Hill, Plymouth.
 1888. †ALLEN, F. J., M.A. 108 Mawson-road, Cambridge.
 1887. †Allen, John. 14 Park-road, St. Anne's-on-the-Sea, viâ Preston.
 1882. *Alverstone, The Right Hon. Lord, G.C.M.G., LL.D., F.R.S. Hornton Lodge, Hornton-street, Kensington, W.
 1887. †Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
 1883. §Amery, John Sparke. Druid, Ashburton, Devon.
 1883. §Amery, Peter Fabyan Sparke. Druid, Ashburton, Devon.
 1884. †AMI, HENRY, M.A., D.Sc., F.G.S. Geological Survey, Ottawa, Canada.
 1905. †Anderson, A. J., M.A., M.B. The Residency, Portswood-road, Green Point, Cape Colony.
 1905. *Anderson, C. L. P.O. Box 2162, Johannesburg.
 1885. *ANDERSON, HUGH KERR. Caius College, Cambridge.

Year of
Election.

1901. *Anderson, James. Ravelston, Kelvinside, Glasgow.
 1892. †Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
 1899. *Anderson, Miss Mary Kerr. 13 Napier-road, Edinburgh.
 1888. *Anderson, R. Bruce. 5 Westminster-chambers, S.W.
 1887. †ANDERSON, Professor R. J., M.D., F.L.S. Queen's College, and
 Atlantic Lodge, Salthill, Galway.
 1905. †Anderson, T. J. P.O. Box 173, Cape Town.
 1880. *ANDERSON, TEMPEST, M.D., D.Sc., F.G.S. (Local Sec. 1881).
 17 Stonegate, York.
 1902. *Anderson, Thomas. Embleton, Osborne Park, Belfast.
 1901. *Anderson, Dr. W. Carrick. 8 Windsor-quadrant, Glasgow.
 1895. †Andrews, Charles W., B.A., D.Sc., F.R.S. British Museum
 (Natural History), S.W.
 1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
 1886. §Andrews, William, F.G.S. Steeple Croft, Coventry.
 1877. §ANGELL, JOHN, F.C.S., F.I.C. 6 Beacons-field, Derby-road,
 Withington, Manchester.
 1900. †Annandale, Nelson. 34 Charlotte-square, Edinburgh.
 1896. †Annett, R. C. F. 4 Buckingham-avenue, Sefton-park, Liverpool.
 1886. †Ansell, Joseph. 27 Bennett's-hill, Birmingham.
 1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.
 1901. †Arakawa, Minozi. Japanese Consulate, 84 Bishopsgate-street
 Within, E.C.
 1900. §Arber, E. A. Newell, M.A., F.L.S. Trinity College, Cambridge.
 1894. †Archibald, A. Holmer, Court-road, Tunbridge Wells.
 1884. *Archibald, E. Douglas. Constitutional Club, W.C.
 1883. §Armistead, Richard. 17 Chambres-road, Southport.
 1883. *Armistead, William. Hillcrest, Oaken, Wolverhampton.
 1903. *ARMSTRONG, E. FRANKLAND, D.Sc., Ph.D. 55 Granville-park,
 Lewisham, S.E.
 1873. *ARMSTRONG, HENRY E., Ph.D., LL.D., F.R.S. (Pres. B, 1885 ;
 Pres. L, 1902 ; Council, 1899-1905), Professor of Chemistry in
 the City and Guilds of London Institute, Central Institution,
 Exhibition-road, S.W. 55 Granville-park, Lewisham, S.E.
 1905. §Armstrong, John. Kamfersdam Mine, near Kimberley, Cape
 Colony.
 1905. §ARNOLD, J. O., Professor of Metallurgy in the University of Shef-
 field.
 1893. *Arnold-Bemrose, H. H., M.A., F.G.S. Ash Tree House, Osmaston-
 road, Derby.
 1904. †Arunachalam, P. Ceylon Civil Service, Colombo, Ceylon.
 1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
 1903. *Ashby, Thomas, jun. The British School, Rome.
 Ashworth, Henry. Turton, near Bolton.
 1903. *Ashworth, J. H., D.Sc. 4 Cluny-terrace, Edinburgh.
 1888. *Ashworth, J. Jackson. Kingston House, Didsbury, near Man-
 chester.
 1890. †Ashworth, J. Reginald, D.Sc. 105 Freehold-street, Rochdale.
 1905. §Askew, T. A. Main-road, Claremont, Cape Colony.
 1875. *Aspland, W. Gaskell. 50 Park Hill-road, N.W.
 1896. *Assheton, Richard, M.A., F.L.S. Grantchester, Cambridge.
 1905. §Assheton, Mrs. Grantchester, Cambridge.
 1903. †Atchison, Arthur F. T., B.Sc. Royal Engineering College,
 Cooper's Hill, Staines.
 1896. §Atkin, George, J.P. Egerton-park, Rockferry.
 1887. †Atkinson, Rev. C. Chetwynd, D.D. Ingestre, Ashton-on-Mersey.
 1898. *Atkinson, E. Cuthbert. Erwood, Beckenham, Kent.

Year of
Election.

1894. *Atkinson, Harold W., M.A. Erwood, Beckenham, Kent.
 1906. §Atkinson, J. J. Cosgrove Priory, Stony Stratford.
 1881. †Atkinson, J. T. The Quay, Selby, Yorkshire.
 1881. †ATKINSON, ROBERT WILLIAM, F.C.S. (Local Sec. 1891.) 44
 Loudoun-square, Cardiff.
 1894. §Atkinson, William. Erwood, Beckenham, Kent.
 1863. *ATTFIELD, J., M.A., Ph.D., F.R.S., F.C.S. Ashlands, Watford,
 Herts.
 1906. §Auden, Dr. G. A. Bootham, York.
 1903. †AUSTIN, CHARLES E. 37 Cambridge-road, Southport.
 1853. *AVEBURY, The Right Hon. Lord, D.C.L., F.R.S. (PRESIDENT,
 1881; TRUSTEE, 1872- ; Pres. D, 1872; Council, 1865-71.)
 High Elms, Farnborough, Kent.
 1877. *AYRTON, W. E., F.R.S. (Pres. A, 1898; Council 1889-96), Pro-
 fessor of Electrical Engineering in the City and Guilds of
 London Institute, Central Institution, Exhibition-road, S.W.
 41 Norfolk-square, W.
 1900. †BACCHUS, RAMSDEN (Local Sec. 1900). 15 Welbury-drive, Brad-
 ford.
 1883. *Bach, Madame Henri. 19 Avenue Bosquet, Paris.
 1906. §Backhouse, James. Daleside, Scarborough.
 1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.
 1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
 1903. †Baden-Powell, Major B. 22 Prince's-gate, S.W.
 1905. §Baikie, Robert. P.O. Box 36, Pretoria, South Africa.
 1883. †Baildon, Dr. 42 Hoghton-street, Southport.
 1883. *Bailey, Charles, F.L.S. Atherstone House, North-drive, St.
 Anne's-on-the-Sea, Lancashire.
 1893. †BAILEY, Colonel F., F.R.G.S. 7 Drummond-place, Edinburgh.
 1887. *Bailey, G. H., D.Sc., Ph.D. Marple Cottage, Marple, Cheshire.
 1905. *Bailey, Harry Percy. Care of India Rubber Co., Ltd., 213 West-
 street, Durban, Natal.
 1905. §Bailey, W. F., C.B. Land Commission, Dublin.
 1894. *BAILY, FRANCIS GIBSON, M.A. Newbury, Juniper Green, Mid-
 lothian.
 1878. †BAILY, WALTER. 4 Roslyn-hill, Hampstead, N.W.
 1897. §BAIN, JAMES. Public Library, Toronto, Canada.
 1905. §Baker, Sir Augustine. 56 Merrion-square, Dublin.
 1882. *BAKER, Sir BENJAMIN, K.C.B., K.C.M.G., LL.D., D.Sc., F.R.S.,
 M.Inst.C.E. (Pres. G, 1885; Council, 1889-96). 2 Queen-
 square-place, Westminster, S.W.
 1886. §Baker, Harry, F.I.C. Epworth House, Moughland-lane, Runcorn.
 1904. †BALFOUR, The Right Hon. A. J., D.C.L., LL.D., M.P., F.R.S.,
 Chancellor of the University of Edinburgh. (PRESIDENT,
 1904.) Whittinghame, Prestonkirk, N.B.
 1894. †BALFOUR, HENRY, M.A. (Pres. H, 1904). 11 Norham-gardens,
 Oxford.
 1905. †Balfour, Mrs. H. 11 Norham-gardens, Oxford.
 1875. †BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R.S., F.R.S.E.,
 F.L.S. (Pres. D, 1894; K, 1901), Professor of Botany in the
 University of Edinburgh. Inverleith House, Edinburgh.
 1883. †Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
 1905. †Balfour, Mrs. J. Dawyck, Stobo, N.B.
 1905. †Balfour, Lewis. 11 Norham-gardens, Oxford.

Year of
Election.

1905. †Balfour, Miss Vera B. Dawyck, Stobo, N.B.
 1878. *Ball, Sir 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. (Pres. A, 1887; Council, 1884-90, 1892-94; Local Sec. 1878), Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
 1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
 1905. †Ballantine, Rev. T. R. Tirmochree, Bloomfield, Belfast.
 1869. †Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
 1890. †Bamford, Professor Harry, M.Sc. 30 Falkland-mansions, Glasgow.
 1899. §Bampton, Mrs. 42 Marine-parade, Dover.
 1905. §Banks, Miss Margaret Pierrepont. 10 Regent-terrace, Edinburgh.
 1898. †Bannerman, W. Bruce, F.S.A. The Lindens, Sydenham-road, Croydon.
 1890. *Barber-Starkey, W. J. S. Aldenham-park, Bridgnorth, Salop.
 1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
 1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
 1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
 1902. †Barcroft, H., D.L. The Glen, Newry, Co. Down.
 1902. †Barcroft, Joseph, M.A., B.Sc. King's College, Cambridge.
 1904. §Barker, B. T. P. Fenswood, Long Ashton, Bristol.
 1906. *Barker, Geoffrey Palgrave. Henstead Hall, near Wrentham, Suffolk.
 1899. §Barker, John H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
 1882. *Barker, Miss J. M. The Fox Covers, Bebington, Cheshire.
 1898. †Barker, W. R. 106 Redland-road, Bristol.
 1889. †Barlow, H. W. L., M.A., M.B., F.C.S. The Park Hospital, Hither Green, S.E.
 1883. †Barlow, J. J. 84 Cambridge-road, Southport.
 1885. *BARLOW, WILLIAM, F. G.S. The Red House, Great Stanmore.
 1905. §Barnard, Miss Annie T., M.B., B.Sc. 32 Chenies-street-chambers, W.C.
 1902. §Barnard, J. E. Park View, Brondesbury Park, N.W.
 1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
 1881. †Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
 1904. †Barnes, Rev. E. W., M.A., F.R.A.S. Trinity College, Cambridge.
 1881. †BARR, ARCHIBALD, D.Sc., M.Inst.C.E., Professor of Civil Engineering in the University, Glasgow.
 1902. *Barr, Mark. The Cedars, Cowley, Middlesex.
 1904. †Barrett, Arthur. 6 Mortimer-road, Cambridge.
 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.
 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.
 1893. *BARROW, GEORGE, F.G.S. Mount Folly, Bodmin, Cornwall.
 1896. §Barrowman, James. Staneacre, Hamilton, N.B.
 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. Falcon Hall, Edinburgh.

Year of
Election.

1858. *Bartholomew, William Hamond, M.Inst.C.E. Ridgeway House, Cumberland-road, Hyde-park, Leeds.
1893. *Barton, Edwin H., D.Sc., F.R.S.E., Professor of Experimental Physics in University College, Nottingham.
1904. *Bartrum, C. O., B.Sc. 3 Holford-road, Hampstead, N.W.
- *Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1888. *BASSETT, 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. (Pres. F, 1894). 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1871. †BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Emeritus Professor of the Principles and Practice of Medicine in University College, London. 8a Manchester-square, W.
1883. †BATEMAN, Sir A. E., K.C.M.G., Controller-General of the Statistical Department, Board of Trade. 7 Whitehall-gardens, S.W.
1884. †BATESON, WILLIAM, M.A., F.R.S. (Pres. D, 1904). St. John's College, Cambridge.
1881. *BATHER, FRANCIS ARTHUR, M.A., D.Sc., F.G.S. British Museum (Natural History), S.W.
1906. §Batty, Mrs. Braithwaite. Ye Gabled House, The Parks. Oxford.
1863. §BAUERMAN, H., F.G.S. 14 Cavendish-road, Balham, S.W.
1904. †Baugh, J. H. Agar. 92 Hatton-garden, E.C.
1905. †Baxter, W. Duncan. P.O. Box 103, Cape Town.
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 S. Hatherop Castle, Fairford, Gloucestershire.
1905. *Bazley, Miss J. M. A. Kilmorie, Ilsham-drive, Torquay, Devon.
Bazley, Sir Thomas Sebastian, Bart., M.A. Kilmorie, Ilsham-drive, Torquay, Devon.
1905. †Beard, Henry. Highwick, Kenilworth, Cape Colony.
1889. §BEARE, Professor T. HUDSON, B.Sc., F.R.S.E., M.Inst.C.E. The University, Edinburgh.
1905. §Beare, Mrs. T. Hudson. 10 Regent-terrace, Edinburgh.
1904. §Beasley, H. C. 25a Prince Alfred-road, Wavertree, Liverpool.
1905. †Beattie, Professor J. C., D.Sc., F.R.S.E. South African College, Cape Town.
1902. †Beatty, H. M., LL.D. Ballymena, Co. Antrim.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, W.
1900. †Beaumont, Professor Roberts, M.I.Mech.E. The University, Leeds.
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. Outer Temple, 222 Strand, W.C.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hall, Buxton, Derbyshire.
1904. §Beckit, H. O. The Schoolhouse, Whitchurch, Salop.
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. (Council, 1870-75). The Chantry, Bradford-on-Avon.
1904. *Bedford, T. G., M.A. 9 Victoria-street, Cambridge.
1891. †Bedlington, Richard. Gadlys House, Aberdare.
1878. †BEDSON, P. PHILLIPS, D.Sc., F.C.S. (Local Sec. 1889), Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.

Year of
Election.

1901. *BEILBY, G. T., F.R.S. (Pres. B, 1905.) 11 University-gardens, Glasgow.
 1905. †Beilby, Hubert. 11 University-gardens, Glasgow.
 1891. *Belinfante, L. L., M.Sc., Assist. Sec. G.S. Burlington House, W.
 1894. †BELL, F. JEFFREY, M.A., F.Z.S. British Museum, S.W.
 Bell, Frederick John. Woodlands, near Maldon, Essex.
 1900. *Bell, H. Wilkinson. Holmehurst, Rawdon, near Leeds.
 1875. †BELL, JAMES, C.B., D.Sc., Ph.D., F.R.S. 52 Cromwell-road, Hove,
 Brighton.
 1871. *BELL, J. CARTER, F.C.S. The Cliff, Higher Broughton, Manchester.
 1883. *Bell, John Henry. 102 Leyland-road, Southport.
 1905. †Bell, W. H. S. P.O. Box 4284, Johannesburg.
 1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
 1904. †Bellars, A. E. Magdalene College, Cambridge.
 1905. †Bender, Rev. A. P., M.A. Synagogue House, Cape Town.
 1883. *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
 1901. †Bennett, Professor Peter. 6 Kelvinhaugh-street, Sandyford,
 Glasgow.
 1905. §Benson, Arthur H., M.A., F.R.C.S. 42 Fitzwilliam-square, Dublin.
 1905. §Benson, Mrs. A. H. 42 Fitzwilliam-square, Dublin.
 1903. §Benson, D. E. Queenwood, 12 Irton-road, Southport.
 1901. *Benson, Miss Margaret J., D.Sc. Royal Holloway College, Egham.
 1887. *Benson, Mrs. W. J. Care of W. J. Benson, Esq., Standard Bank,
 Johannesburg, Transvaal.
 1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
 1904. †Bentley, B. H. The University, Sheffield.
 1905. §Bentley, F. W. Rein Wood, Huddersfield.
 1905. *Bentley, W. C. Rein Wood, Huddersfield.
 1906. §Bentley, William. Fulford Grange, York.
 1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's
 College, Cork.
 1894. §BERKELEY, The Earl of, F.G.S. Foxcombe, Boarshill, near
 Abingdon.
 1905. †Bernacchi, L. C., F.R.G.S. National Liberal Club, Whitehall-
 place, S.W.
 1906. *Bernays, Albert Evan. 41 and 43 Maddox-street, W.
 1898. §Berridge, Miss C. E. 7 Albert-mansions, Lansdowne-road, Croydon.
 1894. §BERRIDGE, DOUGLAS, M.A., F.C.S. The College, Malvern.
 1904. §Berry, R. A. West of Scotland Agricultural College, 6 Blyths-
 wood-square, Glasgow.
 1905. §Bertrand, Captain Alfred. Champel, Geneva.
 1862. †BESANT, WILLIAM HENRY, M.A., D.Sc., F.R.S. St. John's College,
 Cambridge.
 1882. *Bessemer, Henry. Moorlands, Bitterne, Southampton.
 1880. *BEVAN, REV. JAMES OLIVER, M.A., F.S.A., F.G.S. Chillenden
 Rectory, Dover.
 1904. *Bevan, P. V., M.A. Garden-walk, Chesterton, Cambridge.
 1906. §Bevan-Lewis, W., M.D. West Riding Asylum, Wakefield.
 1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
 1903. †Bickerdike, C. F. 1 Boverney-road, Honor Oak-park, S.E.
 1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
 1885. *BIDWELL, SHELFORD, Sc.D., LL.B., F.R.S. Beechmead, Oatlands
 Chase, Weybridge.
 1904. §Bigg-Wither, Colonel A. C. Tilthams, Godalming, Surrey.
 1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion-hill, S.E.
 1898. †Billington, Charles. Heimath, Longport, Staffordshire.
 1901. *Billsland, William, J.P. 28 Park-circus, Glasgow.
 1887. *Bindloss, James B. Elm Bank, Buxton.

Year of
Election.

1884. *Bingham, Colonel Sir John E., Bart. West Lea, Ranmoor, Sheffield.
1881. †BINNIE, Sir ALEXANDER R., M.Inst.C.E., F.G.S. (Pres. G, 1900.)
77 Ladbroke-grove, W.
1888. *Birley, Miss Caroline. 14 Brunswick-gardens, Kensington, W.
1887. *Birley, H. K. Penrhyn, Irlams o' th' Height, Manchester.
1904. §Bishop, A. W. Edwinstowe, Chaucer-road, Cambridge.
1906. §Bishop, J. L. Inland Revenue Office, York.
1894. †Bisset, James, F.R.S.E. 9 Greenhill-park, Edinburgh.
1886. *Bixby, Colonel W. H. Room 501, Federal-building, Chicago,
U.S.A.
1905. †Black, Alexander. 43 Castle-street, Cape Town.
1881. †Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United
Service Club, Edinburgh.
1901. §Black, W. P. M. 136 Wellington-street, Glasgow.
1903. *BLACKMAN, F. F., M.A., D.Sc., F.R.S. St. John's College, Cam-
bridge.
1902. †Blake, Robert F., F.I.C. 66 Malone-avenue, Belfast.
1894. †Blakiston, Rev. C. D. Exwick Vicarage, Exeter.
1900. *Blamires, Joseph. Bradley Lodge, Huddersfield.
1905. †Blamires, Mrs. Bradley Lodge, Huddersfield.
1904. †Blanc, Dr. Gian Alberto. Istituto Fisico, Rome.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Man-
chester.
1887. *Bles, Edward J., M.A., B.Sc. The University, Glasgow.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1902. †Blount, Bertram, F.I.C. 76 & 78 York-street, Westminster, S.W.
1888. †Bloxsom, Martin, B.A., M.Inst.C.E. Hazelwood, Crumpsall
Green, Manchester.
- 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.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1901. §BLYTHSWOOD, The Right Hon. Lord, LL.D. Blythswood, Ren-
frew.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1900. †BODINGTON, Principal N., Litt.D. Yorkshire College, Leeds.
1900. †Boileau, Lieut.-Colonel A. C. T., R.A. Royal Artillery Institution,
Woolwich.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1898. §BOLTON, H., F.R.S.E. The Museum, Queen's-road, Bristol.
1894. §BOLTON, JOHN. 15 Cranley-gardens, Highgate, N.
1898. *BONAR, JAMES, M.A., LL.D. (Pres. F, 1898; Council, 1899-1905.)
Civil Service Commission, Burlington-gardens, W.
1871. *BONNEY, Rev. THOMAS GEORGE, D.Sc., LL.D., F.R.S., F.S.A.,
F.G.S. (SECRETARY, 1881-85; Pres. C, 1886.) 9 Scroope-
terrace, Cambridge.
1888. †Boon, William. Coventry.
1893. †Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *BOOTH, Right Hon. CHARLES, D.Sc., F.R.S., F.S.S. 24 Great
Cumberland-place, W.
1883. †Booth, James. Hazelhurst, Turton.
1876. †Booth, Rev. William H. St. Paul's Rectory, Old Charlton, Kent.
1883. †Boothroyd, Benjamin. Weston-super-Mare.
1901. *Boothroyd, Herbert E., M.A., B.Sc. Sidney Sussex College, Cam-
bridge.

Year of
Election.

1882. §BORN, HENRY, Ph.D., F.C.S. 5 Sutton Court-road, Chiswick, W.
 1901. †Borradaile, L. A., M.A. Selwyn College, Cambridge.
 1876. *BOSANQUET, R. H. M., M.A., F.R.S., F.R.A.S. Castillo Zamora, Realejo-Alto, Teneriffe.
 1903. §Bosanquet, Robert C., M.A., Professor of Classical Archæology in the University of Liverpool. Institute of Archæology, 40 Bedford-street, Liverpool.
 1896. †Bose, Professor J. C., C.I.E., M.A., D.Sc. Calcutta, India.
 1881. §BOTHAMLEY, CHARLES H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Tanglewood, Southside, Weston-super-Mare.
 1872. †Bottle, Alexander. 4 Godwyne-road, Dover.
 1871. *BOTTOMLEY, JAMES THOMSON, M.A., LL.D., 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 in King's College, W.C.
 1905. §BOULENGER, G. A., F.R.S. (Pres. D, 1905.) 8 Courtfield-road, S.W.
 1905. §Boulenger, Mrs. 8 Courtfield-road, S.W.
 1903. §Boulton, W. S., B.Sc., F.G.S., Professor of Geology in University College, Cardiff. 2 Kymin-terrace, Penarth.
 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., D.Sc., F.L.S. (Council, 1903- ; Local Sec., 1894), Linacre Professor of Comparative Anatomy in the University of Oxford. Savile House, Mansfield-road, Oxford.
 1904. *Bousfield, E. G. P. Hungate Mills, York.
 1902. †Bousfield, Sir William. 20 Hyde-park-gate, W.
 1884. †BOVEY, HENRY T., M.A., F.R.S., M.Inst.C.E., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
 1881. *BOWER, F. O., D.Sc., F.R.S., F.R.S.E., F.L.S. (Pres. K, 1898 ; Council, 1900-06), Regius Professor of Botany in the University of Glasgow.
 1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Seal, Sevenoaks.
 1856. *Bowlby, Miss F. E. 4 South Bailey, Durham.
 1898. §BOWLEY, A. L., M.A. (Pres. F, 1906 ; Council, 1906- .) North-court-avenue, Reading.
 1880. †Bowly, Christopher. Cirencester.
 1887. †Bowly, Mrs. Christopher. Cirencester.
 1899. *Bowman, Herbert Lister, M.A., F.G.S. Greenham-common, Newbury.
 1899. *Bowman, John Herbert. Greenham-common, Newbury.
 1887. §Box, Alfred Marshall. Care of the Lancashire and Yorkshire Bank, Huddersfield.
 1895. *BOYCE, Sir RUBERT, M.B., F.R.S., Professor of Pathology in the University of Liverpool.
 1901. †Boyd, David T. Rhinsdale, Ballieston, Lanark.
 1884. *Boyle, R. Vicars, C.S.I. 3 Stanhope-terrace, Hyde Park, W.
 1892. §BOYS, CHARLES VERNON, F.R.S. (Pres. A, 1903 ; Council, 1893-99, 1905- .) 27 The Grove, Boltons, S.W.
 1905. §Boys, Mrs. C. Vernon. 27 The Grove, Boltons, S.W.
 1872. *BRABROOK, Sir EDWARD, C.B., F.S.A. (Pres. H, 1898 ; Pres. F, 1903 ; Council, 1903- .) 178 Bedford-hill, Balham, S.W.
 1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
 1894. *Braby, Ivon. 30 Bernard-gardens, Wimbledon, S.W.
 1905. †Bradford, Wager. P.O. Box 1056, Johannesburg.

Year of
Election.

1893. §Bradley, F.L. Ingleside, Malvern Wells.
 1904. *Bradley, Gustav. Town Hall, Leigh, Lancashire.
 1899. *Bradley, J. W., Assoc.M.Inst.C.E. Westminster City Hall,
 Charing Cross-road, W.C.
 1903. *Bradley, O. Charnock, D.Sc., M.B., F.R.S.E. Royal Veterinary
 College, Edinburgh.
 1892. †Bradshaw, W. Carisbrooke House, The Park, Nottingham.
 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.
 1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
 1905. §Brakhan, A. P.O. Box 4249, Johannesburg.
 1906. §Branfield, Wilfred. 5 Victoria-villas, Uppertorpe, Sheffield.
 1885. *Bratby, William, J.P. Alton Lodge, Hale, Bowdon, Cheshire.
 1905. §Brausewetter, Miss. Roedean School, near Brighton.
 1905. †Bremner, R. S. Westminster-chambers, Dale-street, Liverpool.
 1905. †Bremner, Stanley. Westminster-chambers, Dale-street, Liverpool.
 1902. *Brereton, Cloudesley. Briningham House, Briningham, S.O.,
 Norfolk.
 1898. §Brereton, Cuthbert A., M.Inst.C.E. 21 Delahay-street, S.W.
 1882. †Bretherton, C. E. 26 Palace-mansions, Addison Bridge, W.
 1905. §Brewis, E. 27 Winchelsea-road, Tottenham, N.
 1886. §BRIDGE, T. W., M.A., D.Sc., F.R.S., Professor of Zoology in the
 University of Birmingham.
 1870. *BRIGG, JOHN, M.P. Kildwick Hall, Keighley, Yorkshire.
 1906. §Briggs, John, M.A., F.Z.S. 32 Red Lion-square, W.C.
 1904. *Briggs, William, M.A., LL.D., F.R.A.S. Burlington House, Cam-
 bridge.
 1905. †Brill, J., Litt.D. Grey College, Bloemfontein, South Africa.
 1893. †Briscoe, Albert E., B.Sc., A.R.C.Sc. The Hoppet, Little Baddow,
 Chelmsford.
 1904. §Briscoe, J. J. Bourn Hall, Bourn, Cambridge.
 1905. §Briscoe, Miss. Bourn Hall, Bourn, near Cambridge.
 1898. †BRISTOL, The Right Rev. G. F. BROWNE, D.D., Lord Bishop of.
 17 The Avenue, Clifton, Bristol.
 1879. *BRITAIN, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
 1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. 9 Vanbrugh-hill, Black-
 heath, S.E.
 1906. §Broad, John M. The Elms, Harlesden, N.W.
 1905. *Broadwood, Brigadier-General R. G. The Deodars, Bloemfontein,
 South Africa.
 1905. §Brock, Dr. B. G. P.O. Box 216, Germiston, Transvaal.
 1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
 1883. *Brodie, David, M.D. Slingsby Villa, Regent's Park-road, N.
 1901. †Brodie, T. G., M.D., F.R.S. 4 Lancaster-terrace, Regent's-park,
 N.W.
 1883. *Brodie-Hall, Miss W. L. 5 Devonshire-place, Eastbourne.
 1905. †Brodigan, C. B. Brakpan Mines, Johannesburg.
 1903. †BRODRICK, HAROLD, M.A. (Local Sec., 1903.) 7 Aughton-road,
 Birkdale, Southport.
 1904. †Bromwich, T. J. F.A., M.A., F.R.S., Professor of Mathematics in
 Queen's College, Galway.
 1906. §Brook, Stanley. 18 St. George's-place, York.
 1905. *Brooke, Geoffrey. Christ Church Vicarage, Mirfield, S.O., York-
 shire.

Year of
Election.

1906. §Brooks, F. T. Emmanuel College, Cambridge.
1887. §Brooks, James Howard. Elm Hirst, Wilmslow, near Manchester.
1883. *Brotherton, E. A., M.P. Arthington Hall, Wharfedale, viâ Leeds.
1901. §Brough, Bennett H., F.I.C., F.G.S. 28 Victoria-street, S.W.
1883. *Brough, Mrs. Charles S. 4 Eastern Villas-road, Southsea.
1886. †Brough, Joseph, LL.D., Professor of Logic and Philosophy in University College, Aberystwyth.
1905. †Brown, A. R. Trinity College, Cambridge.
1863. *BROWN, ALEXANDER CRUM, M.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1874; Local Sec. 1871), Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1883. †Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1905. §Brown, Ernest William, M.A., D.Sc., F.R.S., Professor of Mathematics in Haverford College, Haverford, Pennsylvania, U.S.A.
1903. †Brown, F. W. 6 Rawlinson-road. Southport.
1807. §BROWN, HORACE T., LL.D., F.R.S., F.G.S. (Pres. B, 1899; Council, 1904-) 52 Nevern-square, S.W.
1870. *BROWN, J. CAMPBELL, D.Sc., F.C.S., Professor of Chemistry in the University of Liverpool.
1905. †Brown, J. Ellis. Durban, Natal.
1876. §BROWN, JOHN, F.R.S. (Local Sec. 1902.) Longhurst, Dunmurry, Belfast.
1881. *Brown, John, M.D. 2 Glebe-terrace, Rondebosch, Cape Colony.
1895. *Brown, John Charles, 39 Burlington-road, Sherwood, Nottingham.
1905. †Brown, John S. Longhurst, Dunmurry, Belfast.
1905. †Brown, L. Clifford. Beyer's Kloof, Klapmuts, Cape Colony.
1882. *Brown, Mrs. Mary. 2 Glebe-terrace, Rondebosch, Cape Colony.
1898. §Brown, Nicol, F.G.S. 4 The Grove, Highgate, N.
1886. †Brown, R., R.N. Laurel Bank, Barnhill, Perth.
1905. †Brown, R. C. Strathyre, Troyville, Transvaal.
1901. †Brown, R. N. R., B.Sc. University College, Dundee.
1891. §BROWN, T. FORSTER, M.Inst.C.E. (Pres. G, 1891.) Springfort, Stoke Bishop, Bristol.
1906. §Browne, Charles E., B.Sc. Christ's Hospital, Horsham.
1900. *Browne, Frank Balfour, M.A., F.R.S.E., F.Z.S. Sutton Broad Laboratory, Catfield, Great Yarmouth.
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.
1905. *Browne, James Stark, F.R.A.S. The Red House, Mount-avenue, Ealing, W.
1891. †BROWNE, MONTAGU, F.G.S. Corporation Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Browne's-hill, Carlow, Ireland.
1883. †Browning, Oscar, M.A. King's College, Cambridge.
1905. §BRUCE, Colonel DAVID, C.B., M.B., F.R.S. (Pres. I, 1905.) War Office, 68 Victoria-street, S.W.
1905. †Bruce, Mrs. 3P Artillery-mansions, Victoria-street, S.W.
1893. †Bruce, William S. 11 Mount Pleasant, Joppa, Edinburgh.
1900. *Brumm, Charles. Lismara, Grosvenor-road, Birkdale, Southport.
1905. †Brummer, Rev. N. J., M.A., B.D. Blommertein, Three Anchor Bay, Cape Colony.
1896. *Brunner, Right Hon. Sir J. T., Bart., M.P. Druid's Cross, Waver-tree, Liverpool.

Year of
Election.

1868. †BRUNTON, Sir T. LAUDER, M.D., D.Sc., F.R.S. 10 Stratford-place, Cavendish-square, W.
1905. §Brunton, Lady. 10 Stratford-place, Cavendish-square, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
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, D.D., LL.D. Kilmadock, Winnipeg, Canada.
1902. *Bubb, Miss E. Maude. Ullenwood, near Cheltenham.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S., F.R.S.E., Sec. Scottish Meteorological Society. 2 Dean-terrace, Edinburgh.
1902. †Buchanan, Miss Florence, D.Sc. University Museum, Oxford.
1905. §Buchanan, Right Hon. Sir John. Clareinch, Claremont, Cape Town.
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. Christ's College, Cambridge.
1886. *Buckle, Edmund W. 23 Bedford-row, W.C.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1904. §Buckwell, J. C. North Gate House, Pavilion, Brighton.
1893. §BULLEID, ARTHUR, F.S.A. The Old Vicarage, Midsomer Norton, Bath.
1903. *Bullen, Rev. R. Ashington, F.L.S., F.G.S. Englemoor, Heathside-road, Woking, Surrey.
1905. †Burbury, Mrs. A. A. 17 Upper Phillimore-gardens, W.
1905. †Burbury, Miss A. D. 17 Upper Phillimore-gardens, W.
1886. §BURBURY, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, W.C.
1881. †Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1905. †Burdon, E. R., B.A. Devana-terrace, Huntingdon-road, Cambridge.
1894. †BURKE, JOHN B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Colonel Jeffrey H. 824 Sherbrook-street, Montreal, Canada.
1905. †Burmeister, H. A. P. 78 Hout-street, Cape Town.
1904. †Burn, R. H. 21 Stanley-crescent, Notting-hill, W.
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.
1885. *Burnett, W. Kendall, M.A. Migvie House, North Silver-street, Aberdeen.
1905. †Burroughes, James S., F.R.G.S. The Homestead, Seaford, Sussex.
1866. *BURTON, FREDERICK M., F.L.S., F.G.S. Highfield, Gainsborough.
1892. †Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. 11 Union-crescent, Margate.
1904. †Burt, Arthur H., D.Sc. 4 South View, Holgate, York.
1906. §Burt, Philip. St. George's-place, York.
1887. *Bury, Henry. Mayfield House, Farnham, Surrey.
1899. §Bush, Anthony. 43 Portland-road, Nottingham.
1895. †Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1906. §Bushell, H. A. Melton House, Holgate, York.
1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1884. *Butterworth, W. 10 Derbe-street, St. Anne's-on-the-Sea, Lancashire.

Year of
Election.

1905. †Buxton, Miss F. M. 42 Grosvenor-gardens, S.W.
 1905. §Buxton, F. W. 42 Grosvenor-gardens, S.W.
 1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
 1899. †Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.
1861. *Caird, James Key, LL.D. 8 Roseangle, Dundee.
 1905. †Calderwood, J. M. P.O. Box 2295, Johannesburg.
 1901. †Caldwell, Hugh. Blackwood, Newport, Monmouthshire.
 1897. §CALLENDAR, HUGH L., M.A., LL.D., F.R.S. (Council, 1900-06),
 Professor of Physics in the Royal College of Science, S.W.
 1857. †CAMERON, SIR CHARLES A., C.B., M.D. 15 Pembroke-road, Dublin.
 1896. §Cameron, Irving H. 307 Sherbourne-street, Toronto, Canada.
 1901. †Campbell, Archibald. Park Lodge, Albert-drive, Pollokshields,
 Glasgow.
 1897. †Campbell, Colonel J. C. L. Achalader, Blairgowrie, N.B.
 1902. †Campbell, Robert. 21 Great Victoria-street, Belfast.
 1890. †CANNAN, EDWIN, M.A., LL.D., F.S.S. (Pres. F, 1902.) 46 Wel-
 lington-square, Oxford.
 1905. †Cannan, Gilbert. King's College, Cambridge.
 1897. §Cannon, Herbert. Woodbank, Erith, Kent.
 1904. †Capell, Rev. G. M. Passenham Rectory, Stony Stratford.
 1905. *Caporn, Dr. A. W. Roeland-street Baths, Cape Town.
 1894. †CAPPER, D. S., M.A., Professor of Mechanical Engineering in King's
 College, W.C.
 1896. *Carden, H. Vandeleur. Fassaroe, Walmer.
 1902. †Carpenter, G. H., B.Sc., Professor of Zoology in the Royal College
 of Science, Dublin.
 1906. *Carpenter, H. C. H. Heathwaite, Kingston-lane, Teddington.
 1905. §Carpmael, Edward, F.R.A.S., M.Inst.C.E. 24 Southampton-
 buildings, Chancery-lane, W.C.
 1893. †CARR, J. WESLEY, M.A., F.L.S., F.G.S., Professor of Biology in
 University College, Nottingham.
 1906. *Carr, Richard E., British Vice-Consul, Cordoba, Spain.
 1889. †Carr-Ellison, John Ralph. Hedgeley, Alnwick.
 1905. †Carrick, Dr. P.O. Box 646, Johannesburg.
 1867. †CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. (Pres. D, 1886.)
 14 Vermont-road, Norwood, S.E.
 1886. †CARSLAKE, J. BARHAM (Local Sec. 1886). 30 Westfield-road,
 Birmingham.
 1899. †Carshaw, H. S., D.Sc., Professor of Mathematics in the University
 of Sydney, N.S.W.
 1903. *Cart, Rev. Henry. 49 Albert-court, Kensington Gore, S.W.
 1868. *Carteighe, Michael, F.C.S., F.I.C. 180 New Bond-street, W.
 1900. *Carter, Rev. W. Lower, M.A., F.G.S. Belfield, Oxton, Birkenhead.
 1896. †Cartwright, Miss Edith G. 21 York Street-chambers, Bryanston-
 square, W.
 1878. *Cartwright, Ernest H., M.A., M.D. Myskyns, Ticehurst, Sussex.
 1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I. 21 Parsons-lane, Bury,
 Lancashire.
 1862. †Carulla, F. J. R. 84 Rosehill-street, Derby.
 1894. †Carus, Dr. 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, S.W.
 1901. †Carver, Thomas A. B., D.Sc., Assoc.M.Inst.C.E. 118 Napiershall-
 street, Glasgow.

- Year of Election.
1899. *Case, J. Monckton. Town Office, Uitenhage, Cape Colony.
1897. *Case, Willard E. Auburn, New York, U.S.A.
1873. *Cash, William, F.G.S. 35 Commercial-street, Halifax.
1904. †Caspair, W. A. National Physical Laboratory, Bushy House, Teddington, Middlesex.
1900. *Cassie, W., M.A., Professor of Physics in the Royal Holloway College. Brantwood, Englefield Green.
1886. *Cave-Moyle, Mrs. Isabella. St. Paul's Vicarage, Cheltenham. Cayley, Digby. Brompton, near Scarborough.
1905. *Challenor, Bromley. The Firs, Abingdon.
1905. *Challenor, Miss E. M. The Firs, Abingdon.
1905. †Chamberlain, Miss H. H. Ingleneuk, Upper St. John's-road, Sea Point, Cape Colony.
1901. §Chamen, W. A. South Wales Electrical Power Distribution Company, Royal-chambers, Queen-street, Cardiff.
1905. §Champion, G. A. Haraldene, Chelmsford-road, Durban, Natal.
1881. *Champney, John E. 27 Hans-place, S.W.
1902. §Chapman, D. L. 10 Parsonage-road, Withington, Manchester.
1899. §Chapman, Professor Sydney John, M.A. Victoria University, Manchester.
1905. †Chassigneux, E. 12 Tavistock-road, Westbourne-park, W.
1903. †Chaster, G. W. 42 Talbot-road, Southport.
1904. *Chattaway, F. D. Longfield, Kenton-road, Harrow.
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. Hawksmoor, Windermere.
1904. *Chaundy, Theodore William. 49 Broad-street, Oxford.
1900. §Cheesman, W. Norwood, J.P., F.L.S. The Crescent, Selby.
1874. *Chermside, Major-General Sir H. C., R.E., G.C.M.G., C.B. Newstead Abbey, Nottingham.
1879. *Chesterman, W. Belmayne, Sheffield.
1883. †Chinery, Edward F. Monmouth House, Lymington.
1884. †Chipman, W. W. L. 957 Dorchester-street, Montreal, Canada.
1894. †CHISHOLM, G. G., M.A., B.Sc., F.R.G.S. 59 Drakefield-road, Upper Tooting, S.W.
1899. §Chitty, Edward. Sonnenberg, Castle-avenue, Dover.
1899. §Chitty, Mrs. Edward. Sonnenberg, Castle-avenue, Dover.
1899. §Chitty, G. W. Brockhill Park, Hythe, Kent.
1904. †Chivers, John, J.P. Histon, Cambridgeshire.
1882. †Chorley, George. Midhurst, Sussex.
1893. *CHREE, CHARLES, D.Sc., F.R.S. Kew Observatory, Richmond, Surrey.
1900. *Christie, R. J. Duke-street, Toronto, Canada.
1875. *Christopher, George. F.C.S. May Villa, Lucien-road, Tooting-common, S.W.
1876. *CHRYSAL, GEORGE, M.A., LL.D., F.R.S.E. (Pres. A, 1885.) Professor of Mathematics in the University of Edinburgh, 5 Belgrave-crescent, Edinburgh.
1905. †Chudleigh, C. P.O. Box 743, Johannesburg.
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. (Pres. E, 1898.) 216 Cromwell-road, S.W.
1903. §Clapham, J. H., M.A., Professor of Economics in the University of Leeds.

Year of
Election.

1901. §Clark, Archibald B., M.A. 16 Comely Bank-street, Edinburgh.
 1905. *Clark, Cumberland, F.R.G.S. 29 Chepstow-villas, Bayswater, W.
 1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
 1902. †Clark, G. M. Cape Town.
 1881. *Clark, J. Edmund, B.A., B.Sc. Asgarth, Riddlesdown-road,
 Purley, Surrey.
 1901. *Clark, Robert M., B.Sc., F.L.S. 27 Albyn-place, Aberdeen.
 1887. †Clarke, C. Goddard, J.P. South Lodge, Champion Hill, S.E.
 1875. †CLARKE, JOHN HENRY. (Local Sec. 1875.) 4 Worcester-terrace,
 Clifton, Bristol.
 1902. §Clarke, Miss Lilian J., B.Sc., F.L.S. 43 Glasslyn-road, Crouch
 End, N.
 1905. †Clarke, Rev. W. E. C., M.A. P.O. Box 1144, Pretoria.
 1889. *CLAYDEN, A. W., M.A., F.G.S. St. John's, Polsloe-road, Exeter.
 1890. *Clayton, William Wikely. *Gipton Lodge, Leeds.*
 1861. †CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the
 University of Glasgow. 2 The University, Glasgow.
 1905. §Cleland, J. R. 2 The University, Glasgow.
 1905. §Cleland, Mrs. 2 The University, Glasgow.
 1902. §Clements, Olaf P. Tana, St. Bernard's-road, Olton, Warwick.
 1904. §Clerk, Dugald, M.Inst.C.E. 18 Southampton-buildings, W.C.
 1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experi-
 mental Philosophy in the University of Oxford. 3 Bardwell-
 road, Banbury-road, Oxford.
 1906. §Close, Major C. F., R.E., C.M.G., F.R.G.S. Army and Navy
 Club, Pall Mall, S.W.
 1883. *CLOWES, FRANK, D.Sc., F.C.S. (Local Sec. 1893.) The Grange,
 College-road, Dulwich, S.E.
 1891. *Coates, Henry. Pitcullen House, Perth.
 1903. *Coates, W. M. Queens' College, Cambridge.
 1884. §Cobb, John. Fitzherries, Abingdon.
 1895. *COBBOLD, FELIX T., M.A. The Lodge, Felixstowe, Suffolk.
 1864. *Cochrane, James Henry. Burston House, Pittville, Cheltenham.
 1901. †Cockburn, Sir John, K.C.M.G., M.D. 10 Gatestone-road, Upper
 Norwood, S.E.
 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. Passaic, Kew.
 1896. *Coghill, Percy de G. 4 Sunnyside, Prince's Park, Liverpool.
 1884. *Cohen, Sir Benjamin L., Bart. 30 Hyde Park-gardens, W.
 1901. §Cohen, N. L. 11 Hyde Park-terrace, W.
 1901. *Cohen, R. Waley, B.A. 11 Sussex-square, W.
 1906. *Coker, Professor Ernest George, M.A., D.Sc., F.R.S.E. City and
 Guilds of London Technical College, Finsbury, E.C.
 1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
 1895. *Colby, William Henry. Carregwen, Aberystwyth.
 1893. §Cole, Grenville A. J., F.G.S., Professor of Geology in the Royal
 College of Science, Dublin.
 1903. †Cole, Otto B. 551 Boylston-street, Boston, U.S.A.
 1897. §COLEMAN, Dr. A. P. 476 Huron-street, Toronto, Canada.
 1899. §Coleman, William. The Shrubbery, Buckland, Dover.
 1899. †Collard, George. The Gables, Canterbury.
 1892. †Collet, Miss Clara E. 7 Coleridge-road, N.
 1887. †COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Organic Chemistry
 in the University of London. 16 Campden-grove, W.

- Year of Election.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.
1876. †COLLINS, J. H., F.G.S. Crinnis House, Par Station, Cornwall.
1865. *Collins, James Tertius. Church-road, Edgbaston, Birmingham.
1905. †Collins, Rev. Spencer. The Rectory, Victoria West, Cape Colony.
1902. †Collins, T. R. Belfast Royal Academy, Belfast.
1907. §COLSON, ALFRED, M.Inst.C.E. (Local Secretary 1907.) Millstone-lane, Leicester.
1905. *Combs, Rev. Cyril W., M.A. Elverton, Castle-road, Newport, Isle of Wight.
1871. *Connor, Charles C. 4 Queen's Elms, Belfast.
1902. †Conway, A. W. 100 Leinster-road, Rathmines, Dublin.
1903. †Conway, R. Seymour, Litt.D., Professor of Latin in Owens College, Manchester.
1898. §Cook, Ernest H. 27 Berkeley-square, Clifton, Bristol.
1876. *COOKE, CONRAD W. 28 Victoria-street, S.W.
1888. †Cooley, George Parkin. Constitutional Club, Nottingham.
1899. *Coomaraswamy, A. K., B.Sc., F.L.S., F.G.S., Director of the Mineralogical Survey of Ceylon. Kandy, Ceylon.
1902. *Coomaraswamy, Mrs. A. K. Kandy, Ceylon.
1903. §Cooper, Miss A. J. 22 St. John-street, Oxford.
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1878. †Cope, Rev. S. W. Bramley, Leeds.
1904. *COPEMAN, S. MONCKTON, M.D., F.R.S. Local Government Board, Whitehall, S.W.
1904. *Copland, Miss Louisa. 14 Brunswick-gardens, Kensington, W.
1905. †Corben, J. H. Education Department, Klerksdorp, Transvaal.
1901. §Corbett, A. Cameron, M.P. Thornliebank House, Glasgow.
1887. *Corcoran, Bryan. Fairlight, 22 Oliver-grove, South Norwood, S.E.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1883. *Core, Professor Thomas H., M.A. Groombridge House, Withington, Manchester.
1901. *Cormack, Professor J. D., B.Sc. University College, Gower-street, W.C.
1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.
1889. †CORNISH, VAUGHAN, D.Sc., F.R.G.S. 72 Prince's-square, W.
1905. †Cornish-Bowden, A. H. Surveyor-General's Office, Cape Town.
1884. †Cornwallis, F. S. W., M.P., F.L.S. Linton Park, Maidstone.
1888. †Corser, Rev. Richard K. 57 Park Hill-road, Croydon.
1900. §Cortie, Rev. A. L., S.J., F.R.A.S. Stonyhurst College, Blackburn.
1905. †Cory, Professor G. E., M.A. Rhodes University College, Grahams Town, Cape Colony.
1906. §Cotsworth, Moses B. Acomb, York.
1906. §Cotter, J. R. 21 Mayfield-road, Terenure Park, Dublin.
1874. *COTTERILL, J. H., M.A., F.R.S. Braeside, Speldhurst, Kent.
1905. †Cottrill, G. St. John, P.O. Box 4829, Johannesburg.
1904. †Coulter, G. G. 28 Pall Mall, S.W.
1896. †COURTNEY, Right Hon. Lord (Pres. F, 1896). 15 Cheyne-walk, Chelsea, S.W.
1905. §Cousens, R. L. - P.O. Box 4261, Johannesburg.
- Cowan, John. Valleyfield, Pennyquick, Edinburgh.
1872. *Cowan, Thomas William, F.L.S., F.G.S. Upcott House, Taunton, Somersetshire.
1903. †Coward, H. Knowle Board School, Bristol.
1900. †Cowburn, Henry. Dingle Head, Leigh, Lancashire.
1905. †Cowell, John Ray. P.O. Box 2141, Johannesburg.
1895. *COWELL, PHILIP H., M.A., F.R.S. Royal Observatory, Greenwich, and 74 Vanbrugh-park, Blackheath, S.E.

Year of
Election.

1899. †Cowper-Coles, Sherard. 82 Victoria-street, S.W.
 1867. *Cox, Edward. Cardean, Meigle, N.B.
 1906. §Cox, S. Herbert, Professor of Mining in the Royal College of Science, S.W.
 1905. †Cox, W. H. Royal Observatory, Cape Town.
 1902. †Craig, H. C. Strandtown, Belfast.
 1884. §CRAIGIE, Major P. G., C.B., F.S.S. (Pres. F, 1900.) West Wellow, Romsey, Hampshire.
 1906. §Craik, Sir Henry, K.C.B., LL.D., M.P. 5A Dean's-yard, Westminster, S.W.
 1906. §Cramp, William. Redthorn, Whalley-road, Manchester.
 1905. *Cranswick, Wm. Franceys. 34 Boshof-road, Kimberley.
 1906. §CRAVEN, HENRY. (Local Sec. 1906.) Clifton Green, York.
 1887. *Craven, Thomas, J.P. Woodheyces-park, Ashton-upon-Mersey.
 1905. †Crawford, Mrs. A. M. Marchmont, Rosebank, near Cape Town.
 1905. †Crawford, Professor Lawrence, M.A., D.Sc., F.R.S.E. South African College, Cape Town.
 1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Colington-road, Edinburgh.
 1905. †Crawford, W. C., jun. 1 Lockharton-gardens, Colington-road, Edinburgh.
 1871. *CRAWFORD AND BALCARRES, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. 2 Cavendish-square, W.; and Haigh Hall, Wigan.
 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., C.B., R.N., F.R.S. (Pres. E., 1903; Council, 1896-1903.) 9 Hervey-road, Blackheath, S.E.
 1876. *Crewdson, Rev. Canon George. St. Mary's Vicarage, Windermere.
 1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
 1896. †Crichton, Hugh. 6 Rockfield-road, Anfield, Liverpool.
 1904. †Crilly, David. 7 Well-street, Paisley.
 1880. *Crisp, Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting-hill, W.
 1905. §Croft, Miss Mary. 17 Pelham-crescent, S.W.
 1890. *Croft, W. B., M.A. Winchester College, Hampshire.
 1878. *Croke, John O'Byrne, M.A. Clounceagh, Ballingarry-Lacy, Co. Limerick.
 1885. †CROMBIE, J. W., M.A., M.P. (Local Sec. 1885.) Balgownie Lodge, Aberdeen.
 1903. *Crompton, Holland. Binfield, Northwood, Middlesex.
 1901. †CROMPTON, Colonel R. E., C.B., M.Inst.C.E. (Pres. G, 1901.) Kensington-court, W.
 1887. †CROOK, HENRY T., M.Inst.C.E. 9 Albert-square, Manchester.
 1898. §Crooke, William. Langton House, Charlton Kings, Cheltenham.
 1865. §CROOKES, Sir WILLIAM, D.Sc., F.R.S., V.P.C.S. (PRESIDENT, 1898; Pres. B, 1886; Council 1885-91.) 7 Kensington Park-gardens, W.
 1879. †Crookes, Lady. 7 Kensington Park-gardens, W.
 1897. *CROOKSHANK, E. M., M.B. Ashdown Forest, Forest Row, Sussex.
 1905. §Crosfield, Hugh T. Walden, Coombe-road, Croydon.
 1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
 1870. *CROSFIELD, WILLIAM. 3 Fulwood-park, Liverpool.
 1904. §Cross, Professor Charles R. Massachusetts Institute of Technology, Boston, U.S.A.

Year of
Election.

1890. †Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1905. §Cross, Robert. 13 Moray-place, Edinburgh.
1904. *CROSSLEY, A. W., D.Sc., Ph.D., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 10 Crediton-road, West Hampstead, N.W.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry, M.D. 116 Manningham-lane, Bradford.
1906. §Cudworth, W. J. Butt's Close, York.
1883. *CULVERWELL, EDWARD P., M.A., Professor of Education in Trinity College, Dublin.
1883. †Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1898. §Cundall, J. Tudor. 1 Dean-park-crescent, Edinburgh.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1905. §Cunningham, Miss A. 2 St. Paul's-road, Cambridge.
1882. *CUNNINGHAM, Lieut.-Colonel ALLAN, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.
1905. †Cunningham, Andrew. Earlsferry, Campground-road, Mowbray, South Africa.
1877. *CUNNINGHAM, D. J., M.D., D.C.L., F.R.S., F.R.S.E. (Pres. H, 1901 ; Council, 1902-), Professor of Anatomy in the University of Edinburgh.
1885. †CUNNINGHAM, J. T., B.A. Biological Laboratory, Plymouth.
1869. †CUNNINGHAM, ROBERT O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *CUNNINGHAM, Rev. W., D.D., D.Sc. (Pres. F, 1891, 1905.) Trinity College, Cambridge.
1892. †Cunningham-Craig, E. H., B.A., F.G.S. 14A Dublin-street, Edinburgh.
1900. *Cunnington, William A., B.A., Ph.D., F.Z.S. 13 The Chase, Clapham Common, S.W.
1892. *Currie, James, M.A., F.R.S.E. Larkfield, Wardie-road, Edinburgh.
1905. §Currie, Dr. O. J. 24 Longmarket-street, Pietermaritzburg, Natal.
1905. †Currie, W. P. P.O.Box 2010, Johannesburg.
1902. †Curry, Professor M., M.Inst.C.E. 5 King's-gardens, Hove.
1883. †Cushing, Mrs. M. Allee-strasse 16r, Hanover, Germany.
1881. §Cushing, Thomas, F.R.A.S. Allee-strasse 16r, Hanover, Germany.
1905. †Cuthbert, W. M. The Red House, Kenilworth, Cape Colony.
1905. †Cuthbert, Mrs. W. M. The Red House, Kenilworth, Cape Colony.
1898. §Dalby, W. E., D.Sc., M.Inst.C.E., Professor of Civil and Mechanical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W. 45 Clifton-road, Crouch End, N.
1889. *Dale, Miss Elizabeth. 45 Oxford-road, Cambridge.
1906. §Dale, William, F.S.A., F.G.S. The Lawn, Archer's-road, Southampton.
1870. †DALLINGER, Rev. W. H., D.D., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, S.E.
1904. *DALTON, J. H. C., M.D. The Plot, Adams-road, Cambridge.
1862. †DANBY, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1905. §Daniel, Miss A. M. 3 St. John's-terrace, Weston-super-Mare.

Year of
Election.

1896. §Danson, F. C. Liverpool and London Chambers, Dale-street, Liverpool.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1897. §Darbshire, F. V., B.A., Ph.D. South-Eastern Agricultural College, Wye, Kent.
1903. §Darbshire, Dr. Otto V. The University, Manchester.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A. (Local Sec. 1861.) Victoria Park, Manchester.
1904. *Darwin, Charles Galton. Newnham Grange, Cambridge.
1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.
1882. †DARWIN, FRANCIS, M.A., M.B., F.R.S., F.L.S. (Pres. D, 1891; Pres. K, 1904; Council, 1882-84, 1897-1901.) 13 Madingley-road, Cambridge.
1881. *DARWIN, Sir GEORGE HOWARD, K.C.B., M.A., LL.D., F.R.S., F.R.A.S. (PRESIDENT, 1905; Pres. A, 1886; Council, 1886-1892), Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1905. †Darwin, Lady. Newnham Grange, Cambridge.
1878. *DARWIN, HORACE, M.A., F.R.S. The Orchard, Huntingdon-road, Cambridge.
1894. *DARWIN, Major LEONARD, Hon. Sec. R.G.S. (Pres. E, 1896; Council, 1899-1905.) 12 Egerton-place, South Kensington, S.W.
1880. *DAVEY, HENRY, M.Inst.C.E. Parliament-chambers, Great Smith-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.
1904. §Davidge, H. T., B.Sc., Professor of Electricity in the Ordnance College, Woolwich.
1902. *Davidson, S. C. Seacourt, Bangor, Co. Down.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1904. §Davies, Henry N. St. Chad's, Weston-super-Mare.
1906. §Davies, S. H. White Cross Lodge, York.
1893. *Davies, Rev. T. Witton, B.A., Ph.D., Professor of Semitic Languages in University College, Bangor, North Wales.
1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1873. *Davis, Alfred. 37 Ladbroke-grove, W.
1905. †Davis, C. R. S. National Bank-buildings, Johannesburg.
1896. *Davis, John Henry Grant. Hillsborough, Wednesbury, Staffordshire.
1905. §Davis, Luther. 20 Frogmore-street, Abergavenny.
1885. *Davis, Rev. Rudolf. 23 Northfield, Bridgwater.
1905. †Davy, Mrs. Alice Burt. P.O. Box 434, Pretoria.
1905. †Davy, Joseph Burt, F.R.G.S., F.L.S. P.O. Box 434, Pretoria.
1860. *Dawes, John T. The Lilacs, Prestatyn, North Wales.
1864. †DAWKINS, W. BOYD, D.Sc., F.R.S., F.S.A., F.G.S. (Pres. C, 1888; Council, 1882-88), Professor of Geology and Palæontology in the University of Manchester. Fallowfield House, Fallowfield, Manchester.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington Hall, Burnsall, Skipton-in-Craven.
1901. *Dawson, P. The Acre, Maryhill, Glasgow.
1905. †Dawson, Mrs. The Acre, Maryhill, Glasgow.
1884. †DAWSON, SAMUEL. (Local Sec. 1884.) 258 University-street, Montreal, Canada.
1906. §Dawson, W. G. Hessle, R.S.O., East Yorks.

Year of
Election.

1870. *DEACON, G. F., LL.D., M.Inst.C.E. (Pres. G, 1897.) 19 Warwick-square, S.W.
1900. §Deacon, M. Whittington, House, near Chesterfield.
1901. *Deasy, Capt. H. H. P. Cavalry Club, Piccadilly, W.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1866. †DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. (Pres. B, 1869 ; Council, 1870-75.) 4 Schlangenberg, Cassel, Hessen.
1893. *Deeley, R. M. 38 Charnwood-street, Derby.
1878. †Delany, Rev. William. University College, Dublin.
1896. §Dempster, John. Tynron, Noctorum, Birkenhead.
1902. †Dendy, Arthur, D.Sc., F.L.S., Professor of Zoology in King's College, London, W.C.
1889. §DENNY, ALFRED, F.L.S., Professor of Biology in the University of Sheffield.
1905. †Denny, G. A. 603-4 Consolidated-buildings, Fox-street, Johannesburg.
1896. *DERBY, The Right Hon. the Earl of, K.G., G.C.B. Knowsley, Prescott, 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.
1903. †Devereux, Rev. E. R. Price. Drachenfeld, Tenison-avenue, Cambridge.
1899. †DEVONSHIRE, The Duke of, K.G., D.C.L., F.R.S. Devonshire House, Piccadilly, W.
1868. *DEWAR, Sir JAMES, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., V.P.C.S., Fullerman Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. (PRESIDENT, 1902 ; Pres. B, 1879 ; Council, 1883-88.) 1 Scroope-terrace, Cambridge.
1881. †Dewar, Lady. 1 Scroope-terrace, Cambridge.
1905. †Dewar, W. R. Agricultural Department, Bloemfontein, South Africa.
1884. *Dewar, William, M.A. Horton House, Rugby.
1905. †Dewhurst, Miss May. Pembroke House, Oxford-road, Colchester.
1901. †Dick, George Handasyde. 31 Hamilton-drive, Hillhead, Glasgow.
1906. §Dickinson, Miss F. A. Burton House, Clifton, York.
1904. †Dickson, Charles Scott, K.C., LL.D. Carlton Club, Pall Mall, S.W.
1881. †Dickson, Edmund, M.A., F.G.S. 2 Starkie-street, Preston.
1887. §DICKSON, H. N., D.Sc., F.R.S.E., F.R.G.S. The Lawn, Upper Redlands-road, Reading.
1902. §Dickson, James D. Hamilton, M.A., F.R.S.E. 6 Cranmer-road, Cambridge.
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.
1901. §Dines, W. H., F.R.S. Oxshott, Leatherhead.
1900. §DIVERS, Dr. EDWARD, F.R.S. (Pres. B, 1902.) 3 Canning-place, Palace Gate, W.
1898. *Dix, John William S. Hampton Lodge, Durdham Down, Clifton, Bristol.
1905. †Dixey, F. A., M.A., M.D. Wadham College, Oxford.
1899. *DIXON, A. C., D.Sc., F.R.S. Professor of Mathematics in Queen's College, Belfast. Almora, Myrtlefield-park, Belfast.
1874. *DIXON, A. E., M.D., Professor of Chemistry in Queen's College, Cork.

Year of
Election.

1900. †Dixon, A. Francis, Sc.D., Professor of Anatomy in the University of Dublin.
1905. †Dixon, Miss E. K. 16 Mount Pleasant, Darlington.
1888. §Dixon, Edward T. Racketts, Hythe, Hampshire.
1900. *Dixon, Captain George, M.A. St. Bees, Cumberland.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S. (Pres. B, 1894), Professor of Chemistry in the Victoria University, Manchester.
1902. †Dixon, Henry H., D.Sc., 23 Northbrook-road, Dublin.
1902. †Dixon, W. V. Scotch Quarter, Carrickfergus.
1896. §Dixon-Nuttall, F. R. Ingleholme, Eccleston Park, Prescott.
1890. †Dobbie, James J., D.Sc., F.R.S., Director of the Museum of Science and Art, Edinburgh.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. Fylde Cottage, Branksome-avenue, Bournemouth.
1902. †Dobbs, F. W. 2 Willowbrook, Eton, Windsor.
1905. †Dobson, Professor J. H. Transvaal Technical Institute, Johannesburg.
1876. †Dodds, J. M. St. Peter's College, Cambridge.
1905. †Dodds, Dr. W. J. Valkenberg, Mowbray, Cape Colony.
1889. †Dodson, George, B.A. Downing College, Cambridge.
1904. §Doncaster, Leonard. The University, Birmingham.
1896. †Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1901. †Donnan, F. G. University College, Gower-street, W.C.
1905. †Donnan, H. Allandale, Claremont, Cape Colony.
1905. †Donner, Arthur. Helsingfors, Finland.
1905. §Donovan, Surgeon-General William, C.B. Army Headquarters, Pretoria.
1905. §Dornan, S. S. Training Institution, Morija, Basutoland, South Africa.
1863. *Doughty, Charles Montagu. 26 Grange-road, Eastbourne.
1905. †Douglas-McMillan, Mrs. A. 31 Ford-street, Jeppestown, Transvaal.
1884. †Dove, Miss Frances. Wycombe Abbey School, Buckinghamshire.
1903. †Dow, Miss Agnes R. Flat 1, 27 Warrington-crescent, W.
1884. *Dowling, D. J. Sycamore, Clive-avenue, Hastings.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. Merry Hall, Ashted, Surrey.
1883. †Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1905. †Drew, H. W., M.B., M.R.C.S. Mocollup Castle, Ballyduff, S.O., Co. Waterford.
1906. *Drew, Joseph Webster, M.A., LL.M. Fashoda, Scarborough.
1906. *Drew, Mrs. Fashoda, Scarborough.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. (Local Sec., 1894.) Yardley Lodge, 9 Crick-road, Oxford.
1905. †Drury, H. P.O. Box 2305, Johannesburg.
1905. †Drury, Mrs. H. P.O. Box 2305, Johannesburg.
1892. †Du Bois, Professor Dr. H. Herwarthstrasse 4, Berlin, N.W.
1905. †Dubois, Raymond, B.Sc. Groot Constantia, Wynberg, Cape Colony.
1905. †Dubois, Mrs. Raymond. Groot Constantia, Wynberg, Cape Colony.
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. 7 Grey Friars, Chester.
1900. *Duckworth, W. L. H., M.D., Sc.D. Jesus College, Cambridge.
1895. *Duddell, William. 47 Hans-place, S.W.

Year of
Election.

1906. §Dudgeon, Gerald C., Superintendent of Agriculture for British West Africa.
1904. †Duffield, W. G. 5 Bridge-approach, Teddington, Middlesex.
1890. †Dufton, S. F. Trinity College, Cambridge.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1893. *Dunell, George Robert. 33 Spencer-road, Grove Park, Chiswick, W.
1896. *DUNKERLEY, STANLEY, D.Sc., M.Inst.C.E., Professor of Engineering in the Victoria University, Manchester.
1876. †Dunnachie, James. 48 West Regent-street, Glasgow.
1884. §Dunnington, Professor F. P. University of Virginia, Charlottesville, Virginia, U.S.A.
1893. *Dunstan, M. J. R., Principal of the South-Eastern Agricultural College, Wye, Kent.
1891. †Dunstan, Mrs. South-Eastern Agricultural College, Wye, Kent.
1885. *DUNSTAN, Professor WYNDHAM, M.A., LL.D., F.R.S., V.P.C.S. (Pres. B, 1906; Council, 1905-), Director of the Imperial Institute, S.W.
1905. †Dutton, C. L. O'Brien. High Commissioner's Office, Johannesburg.
1895. *DWERRYHOUSE, ARTHUR R., M.Sc., F.G.S. Glyn Garth, Weetwood-lane, Headingley, Leeds.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1895. §Dymond, Thomas S., F.C.S. Savile Club, Piccadilly, W.
1905. †DYSON, F. W., M.A., F.R.S. (Council, 1905-), Astronomer Royal for Scotland and Professor of Practical Astronomy in the University of Edinburgh.
1905. †Earp, E. J. P.O. Box 538, Cape Town.
1899. †East, W. H. Municipal School of Art, Science, and Technology, Dover.
1871. *EASTON, EDWARD (Pres. G, 1878; Council, 1879-81). 22 Vincent-square, Westminster, S.W.
1893. *Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1906. §Ebbs, Mrs. A. B. Tuborg, Durham-avenue, Bromley, Kent.
1905. §Ebden, Hon. Alfred. Belmont, Rondebosch, Cape Colony.
1903. †Eccles, W. H., D.Sc. 16 Worfield-street, Battersea, S.W.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
- *Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. Sywell House, Llandudno.
1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889; Council, 1879-86, 1891-98), 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. 4 Chichester-terrace, Kemp Town, Brighton.
1901. *EDRIDGE-GREEN, F. W., M.D., F.R.C.S. Hendon Grove, Hendon, N.W.
1905. †Edwards, Bidewell. 80 St. George's-street, Cape Town.
1899. §Edwards, E. J., Assoc.M.Inst.C.E. 232 Trinity-road, Wandsworth, S.W.
1903. †Edwards, Mrs. Emily. Norley Grange, 73 Leyland-road, Southport.
1903. †Edwards, Francis. Norley Grange, 73 Leyland-road, Southport.
1903. †Edwards, Miss Marion K. Norley Grange, 73 Leyland-road, Southport.

- Year of Election.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1901. †Eggar, W. D. Willowbrook, Eton, Windsor.
1890. §Eldford, Percy. St. John's College, Oxford.
1885. *ELGAR, FRANCIS, LL.D., F.R.S., F.R.S.E., M.Inst.C.E. 34 Leadenhall-street, E.C.
1904. §Eliot, Sir John, K.C.I.E., M.A., F.R.S. 79 Alleyn-park, Dulwich, S.E.
1901. *Elles, Miss Gertrude L. Newnham College, Cambridge.
1904. †Elliot, Miss Agnes I. M. Newnham College, Cambridge.
1904. §Elliot, R. H. Clifton Park, Kelso, N.B.
1904. †Elliot, T. R. B. Holme Park, Rotherfield, Sussex.
1891. †Elliott, A. C., D.Sc., M.Inst.C.E., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1905. §Elliott, C. C., M.D. 5 Bureau-street, Cape Town.
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
- Elliott, John Fogg. Elvet Hill, Durham.
1906. §Ellis, David. Technical College, Glasgow.
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1906. §ELLIS, HERBERT (VICE-PRESIDENT, 1907). 120 Regent-road, Leicester.
1880. *ELLIS, JOHN HENRY (Local Sec. 1883). 3 Carlisle-terrace, The Hoe, Plymouth.
1891. §Ellis, Miss M. A. 129 Walton-street, Oxford.
- Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1906. §ELMHIRST, CHARLES E. (Local Sec. 1906.) 29 Mount-vale, York.
1887. §ELWORTHY, FREDERICK T., F.S.A. Foxdown, Wellington, Somerset.
1884. †Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. †Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1869. *Enys, John Davies. Enys, Penryn, Cornwall.
1894. †*Erskine-Murray, James, D.Sc., F.R.S.E. University College, Nottingham.*
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.
1887. *Estcourt, Charles, F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1889. *EVANS, A. H., M.A. 9 Harvey-road, Cambridge.
1905. †Evans, Mrs. A. H. 9 Harvey-road, Cambridge.
1870. *EVANS, ARTHUR JOHN, M.A., LL.D., F.R.S., F.S.A. (Pres. H, 1896.) Youlbury, Abingdon.
1887. *Evans, Mrs. Isabel. Hoghton Hall, Hoghton, near Preston.
1883. *Evans, Mrs. James C. Casewell Lodge, Llanwrtyd Wells, South Wales.
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. (PRESIDENT, 1897; Pres. C, 1878; Pres. H, 1890; Council, 1868-74, 1875-82, 1889-96.) Britwell, Berkhamsted, Herts.
1897. *Evans, Lady. Britwell, Berkhamsted, Herts.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1905. †Evans, R. O. Ll. Broom Hall, Chwilog, R.S.O., Carnarvonshire.
1865. †EVANS, SEBASTIAN, M.A., LL.D. Abbot's Barton, Canterbury.
1905. †Evans, T. H. 9 Harvey-road, Cambridge.
1905. †Evans, Thomas H. P.O. Box 1276, Johannesburg.

Year of
Election.

1865. *Evans, William. The Spring, Kenilworth.
 1903. †Evatt, E. J., M.B. 8 Kyveilog-street, Cardiff.
 1871. †Eve, H. Weston, M.A. 37 Gordon-square, W.C.
 1902. *Everett, Percy W. Oaklands, Elstree, Hertfordshire.
 1872. †EVERSLEY, Right Hon. Lord, F.R.S. (Pres. F, 1879; Council, 1878-80.) 18 Bryanston-square, W.
 1883. †Eves, Miss Florence. Uxbridge.
 1881. †EWART, J. COSSAR, M.D., F.R.S. (Pres. D, 1901), Professor of Natural History in the University of Edinburgh.
 1874. †EWART, Sir W. QUARTUS, Bart. (Local Sec. 1874). Glenmachan, Belfast.
 1876. *EWING, JAMES ALFRED, M.A., LL.D., F.R.S., F.R.S.E., M.Inst.C.E. (Pres. G, 1906), Director of Naval Education. Admiralty, S.W.
 1903. §Ewing, Peter, F.L.S. The Frond, Uddingston, Glasgow.
 1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
 1905. †Eyre, Dr. G. G. Claremont, Cape Colony.
 Eyton, Charles. Hendred House, Abingdon.
 1906. *Faber, George D., M.P. 14 Grosvenor-square, W.
 1901. §Fairgrieve, M. McCallum. 115 Dalkeith-road, Edinburgh.
 1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
 1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Cheshire.
 1902. §Fallaize, E. N., M.A. 25 Alexandra-mansions, Middle-lane, Hornsey, N.
 1898. †Faraday, Miss Ethel R., M.A. Ramsay Lodge, Levenshulme, near Manchester.
 1877. §FARADAY, F. J., F.L.S., F.S.S. (Local Sec. 1887.) Colledge-chambers, 17 Brazennose-street, Manchester.
 1902. §Faren, William. 11 Mount Charles, Belfast.
 1892. *FARMER, J. BRETLAND, M.A., F.R.S., 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, Mrs. Ernest. Broadlands, Goldthorn Hill, Wolverhampton.
 1904. †Farnworth, Miss Olive. Broadlands, Goldthorn Hill, Wolverhampton.
 1885. *Farquharson, Mrs. R. F. O. Tillydrine, Kincardine O'Neil, N.B.
 1905. †Farrar, Edward. P.O. Box 1242, Johannesburg.
 1904. §Farrer, Sir William. 18 Upper Brook-street, W.
 1903. §Faulkner, Joseph M. 13 Great Ducie-street, Strangeways, Manchester.
 1890. *Fawcett, F. B. University College, Bristol.
 1906. §Fawcett, Henry Hargreaves. 20 Margaret-street, Cavendish-square, W.
 1900. †FAWCETT, J. E., J.P. (Local Sec. 1900.) Low Royd, Apperley Bridge, Bradford.
 1902. *Fawsitt, C. E., Ph.D. 9 Foremount-terrace, Dowanhill, Glasgow.
 1906. *Fearnside, Edwin G., D.Sc. Horbury, Wakefield.
 1901. *Fearnside, W. G., B.A., F.G.S. Sidney Sussex College, Cambridge.
 1905. §Feilden, Colonel H. W., C.B. Burwash, Sussex.
 1900. *Fennell, William John. Deramore Drive, Belfast.
 1904. †Fenton, H. J. H., M.A., F.R.S. 19 Brookside, Cambridge.
 1906. §Ferguson, Allan. Cemetery Hotel, Newhall-lane, Preston.
 1902. †FERGUSON, GODFREY W. (Local Sec. 1902.) Cluan, Donegall Park, Belfast.

Year of
Election.

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. Calton Lodge, Cinnamon-gardens, Colombo, Ceylon.
1901. †Ferguson, R. W. Municipal Technical School, the Gamble Institute, St. Helens, Lancashire.
1883. *Ferne, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1905. *Ferrar, H. T. Survey Department, Cairo.
1905. §Ferrar, J. E. Sidney Sussex College, 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.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1897. †Field, George Wilton, Ph.D. Room 158, State House, Boston, Massachusetts, U.S.A.
1906. §Filon, L. N. G., D.Sc. Vega, Blenheim Park-road, Croydon.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
1905. §Fincham, G. H. Hopewell, Invami, Cape Colony.
1878. *Findlater, Sir William. 22 Fitzwilliam-square, Dublin.
1905. §Findlay, Alexander, M.A., Ph.D., D.Sc., Lecturer on Physical Chemistry in the University of Birmingham.
1904. *Findlay, J. J., Ph.D., Professor of Education in the University of Manchester.
1902. §Finnegan, J., B.A., B.Sc. Kelvin House, Botanic-avenue, Belfast.
1895. §Fish, Frederick J. Spursholt, Park-road, Ipswich.
1902. †Fisher, J. R. Cranfield, Fortwilliam Park, Belfast.
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.
1887. *Fison, Alfred H., D.Sc. 47 Dartmouth-road, Willesden Green, N.W.
1871. *FISON, Sir FREDERICK W., Bart., M.A., M.P., F.C.S. 64 Pont-street, S.W.
1883. †Fitch, Rev. J. J. 5 Chambres-road, Southport.
1885. *FITZGERALD, Professor MAURICE, B.A. (Local Sec. 1902.) 32 Eglantine-avenue, Belfast.
1894. †Fitzmaurice, M., C.M.G., M.Inst.C.E. London County Council, Spring-gardens, S.W.
1888. *FITZPATRICK, Rev. THOMAS C., President of Queens' College, Cambridge.
1904. †Flather, J. H., M.A. Camden House, 90 Hills-road, Cambridge.
1904. §Fleming, Sir James. 21 Norse-road, Scotstoun, Glasgow.
1890. †Fletcher, B. Morley. 7 Victoria-street, S.W.
1892. †Fletcher, George, F.G.S. Dawson Court, Blackrock, Co. Dublin.
1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S. (Pres. C, 1894), Keeper of Minerals, British Museum (Natural History), Cromwell-road, S.W. 35 Woodville-gardens, Ealing, W.
1901. †Flett, J. S., M.A., D.Sc., F.R.S.E. 28 Jermyn-street, S.W.
1906. §Fleury, H. J. University College, Aberystwyth.
1905. *Flint, Rev. W., D.D. Houses of Parliament, Cape Town.
1889. †Flower, Lady. 26 Stanhope-gardens, S.W.
1905. †Flowers, Frank. United Buildings, Foxburgh, Johannesburg.
1890. *FLUX, A. W., M.A., Professor of Political Economy in McGill University, Montreal, Canada.
1877. †Foale, William. The Croft, Madeira Park, Tunbridge Wells.
1903. §Foord-Kelcey, W., Professor of Mathematics in the Royal Military Academy, Woolwich. The Shrubbery, Shooter's Hill, S.E.
1906. §Forbes, Charles Mansfeldt. 1 Oriel-crescent, Scarborough.

Year of
Election.

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.
1905. §FORBES, Major W. LACHLAN, Sec.R.Scot.G.S. Queen-street, Edinburgh.
1890. †FORD, J. RAWLINSON (Local Sec. 1890). Quarry Dene, Weetwood-lane, Leeds.
1875. *FORDHAM, H. GEORGE. Odsey, Ashwell, Baldock, Herts.
1887. †FORREST, The Right Hon. Sir JOHN, G.C.M.G., F.R.G.S., F.G.S., Perth, Western Australia.
1902. §FORSTER, M. O., Ph.D., D.Sc., F.R.S. Royal College of Science, S.W.
1883. †FORSYTH, A. R., M.A., D.Sc., F.R.S. (Pres. A, 1897, 1905), Sadlerian Professor of Pure Mathematics in the University of Cambridge. Trinity College, Cambridge.
1857. *FOSTER, GEORGE CAREY, B.A., LL.D., D.Sc., F.R.S. (GENERAL TREASURER, 1898-1904; Pres. A, 1877; Council, 1871-76, 1877-82.) Ladywalk, Rickmansworth.
1859. *FOSTER, Sir MICHAEL, K.C.B., M.A., M.D., LL.D., D.C.L., F.R.S., F.L.S. (PRESIDENT, 1899; GEN. SEC. 1872-76; Pres. I, 1897; Council, 1871-72.) Great Shelford, Cambridge.
1901. §FOSTER, T. Gregory, Ph.D., Principal of University College, London. Chester-road, Northwood, Middlesex.
1903. †FOURCADE, H. G. P.O., Storms River, Humansdorp, Cape Colony.
1905. §FOWLDs, Hiram. Keighley, Yorkshire.
1906. §FOWLER, Oliver H., M.R.C.S. Ashcroft House, Cirencester.
1883. *FOX, Charles. The Pynes, Warlingham-on-the-Hill, Surrey.
1883. §FOX, Sir CHARLES DOUGLAS, M.Inst.C.E. (Pres. G, 1896.) 28 Victoria-street, Westminster, S.W.
1904. *FOX, Charles J. J., B.Sc., Ph.D. 33 Ashley-road, Crouch Hill, N.
1904. §FOX, F. Douglas, M.A., M.Inst.C.E. 19 The Square, Kensington, W.
1905. §FOX, Mrs. F. Douglas. 19 The Square, Kensington, W.
1883. †FOX, Howard, F.G.S. Rosehill, Falmouth.
1847. *FOX, Joseph Hoyland. The Clive, Wellington, Somerset.
1900. *FOX, Thomas. Pyles Thorne House, Wellington, Somerset.
1881. *FOXWELL, HERBERT S., M.A., F.S.S. (Council, 1894-97), Professor of Political Economy in University College, London. St. John's College, Cambridge.
1905. †FRAMES, Henry J. Talana, St. Patrick's-avenue, Parktown, Johannesburg.
1905. †FRAMES, Mrs. Talana, St. Patrick's-avenue, Parktown. Johannesburg.
1905. †FRANCKE, M. P.O. Box 1156, Johannesburg.
1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S. (Pres. B, 1901), Professor of Chemistry in the University of Birmingham.
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. (Local Sec. 1885.) 232 Union-street, Aberdeen.
1906. *FRASER, Miss Helen C. I., B.Sc., F.L.S. Royal Holloway College, Egham, Surrey.
1865. *FRASER, JOHN, M.A., M.D., F.G.S. Chapel Ash, Wolverhampton.
1871. †FRASER, Sir 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.

Year of
Election.

1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1082, Drexel-building, Philadelphia, U.S.A.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. (Pres. F, 1892; Council, 1897-1903.) 4 Lower Sloane-street, S.W.
1906. §French, Fleet-Surgeon A. M. Langley, Beaufort-road, Kingston-on-Thames.
1905. †French, Sir Somerset R., K.C.M.G. Erritt Lodge, Kenilworth, Cape Colony.
1886. †FRESHFIELD, DOUGLAS W., F.R.G.S. (Pres. E, 1904.) 1 Airlie-gardens, Campden Hill, W.
1901. †Frew, William, Ph.D. King James-place, Perth.
1887. *Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1906. §Fritsch, Dr. F. E. 7 Prout-grove, Neasden, N.W.
1892. *Frost, Edmund, M.D. Chesterfield-road, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. 55 Kensington-court, W.
1898. †FRY, The Right Hon. Sir EDWARD, D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1905. †Fry, H. P.O. Box 46, Johannesburg.
1875. *Fry, Joseph Storrs. 16 Upper Belgrave-road, Clifton, Bristol.
1905. *Fry, William, jun., J.P., F.R.G.S. Wilton House, Merrion-road, Dublin.
1898. †Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1859. †FULLER, FREDERICK, M.A. (Local Sec. 1859.) 9 Palace-road, Surbiton.
1869. †FULLER, G., M.Inst.C.E. (Local Sec. 1874.) 71 Lexham-gardens, Kensington, W.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1850. †GAIRDNER, Sir W. T., K.C.B., M.D., LL.D., F.R.S. 32 George-square, Edinburgh.
1885. *Galloway, Alexander. Dirgarve, Aberfeldy, N.B.
1875. †GALLOWAY, W. Cardiff.
1887. *Galloway, W. J. The Cottage, Seymour-grove, Old Trafford, Manchester.
1905. §Galpin, Ernest E. Bank of Africa, Queenstown, Cape Colony.
1899. §Galton, Lady Douglas. Himbleton Manor, Droitwich.
1860. *GALTON, FRANCIS, M.A., D.C.L., D.Sc., F.R.S., F.R.G.S. (GEN. SEC. 1863-68; Pres. E, 1862, 1872; Pres. H, 1885; Council, 1860-63.) 42 Rutland-gate, Knightsbridge, S.W.
1870. §Gamble, Lieut.-Colonel Sir D., Bart., K.C.B. St. Helens, Lancashire.
1888. *GAMBLE, J. SYKES, C.I.E., M.A., F.R.S., F.L.S. Highfield, East Liss, Hants.
1868. †GAMGEE, ARTHUR, M.D., F.R.S. (Pres. D, 1882; Council, 1888-90.) 5 Avenue du Kursaal, Montreux, Switzerland.
1899. *Garcke, E. Ditton House, near Maidenhead.
1898. †Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
1905. †Gardiner, J. H. 59 Wroughton-road, Balham, S.W.
1900. †Gardiner, J. Stanley, M.A. Gonville and Caius College, Cambridge.
1887. †GARDINER, WALTER, M.A., D.Sc., F.R.S. St. Awdreys, Hills-road, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.

Year of
Election.

1905. †Garlick, John. Thornibrae, Green Point, Cape Town.
 1905. †Garlick, R. C. Thornibrae, Green Point, Cape Town.
 1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.
 1882. †Garnett, William, D.C.L. London County Council, Victoria Embankment, W.C.
 1883. †GARSON, J. G., M.D. (ASSIST. GEN. SEC. 1902-04.) Moorcote, Eversley, Winchfield.
 1903. †Garstang, A. H. 20 Roe-lane, Southport.
 1903. *Garstang, T. James, M.A. Bedale's School, Petersfield, Hampshire.
 1894. *GARSTANG, WALTER, M.A., F.Z.S. Marine Biological Laboratory, Lowestoft.
 1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
 1905. †Garthwaite, E. H. B.S.A.Co., Bulawayo, South Africa.
 1889. †GARWOOD, Professor E. J., M.A., F.G.S. University College, Gower-street, W.C.
 1870. *Gaskell, Holbrook. Erindale, Frodsham, Cheshire.
 1905. †Gaskell, Miss C. J. The Uplands, Great Shelford, Cambridge.
 1905. †Gaskell, Miss M. A. The Uplands, Great Shelford, Cambridge.
 1896. *GASKELL, WALTER HOLBROOK, M.A., M.D., LL.D., F.R.S. (Pres. I, 1896; Council, 1898-1901.) The Uplands, Great Shelford, Cambridge.
 1906. §Gaster, Leon. 32 Victoria-street, S.W.
 1905. †Gaughren, Right Rev. Dr. M. Dutoitspan-road, Kimberley.
 1906. §Gavey, H. Myddelton, M.R.C.S. 16 Broadwater Down, Tunbridge Wells.
 1905. *Gearon, Miss Susan. 55 Buckleigh-road, Streatham Common, S.W.
 1867. †GEIKIE, Sir ARCHIBALD, LL.D., D.Sc., Sec.R.S., F.R.S.E., F.G.S. (PRESIDENT, 1892; Pres. C, 1867, 1871, 1899; Council, 1888-1891.) 3 Sloane-court, S.W.
 1871. †GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1889; Pres. E, 1892), Murchison Professor of Geology and Mineralogy in the University of Edinburgh. Kilmorie, Colinton-road, Edinburgh.
 1898. §Gemmill, James F., M.A., M.D. 21 Endsleigh-gardens, Partick-hill, Glasgow.
 1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
 1905. §Gentleman, Miss A. A. 9 Abercromby-place, Stirling.
 1875. *George, Rev. Hereford Brooke, M.A., F.R.G.S. Holywell Lodge, Oxford.
 1902. *Gepp, Antony, M.A., F.L.S. British Museum (Natural History), Cromwell-road, S.W.
 1899. *Gepp, Mrs. A. 26 West Park-gardens, Kew.
 1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
 1905. §Gibbs, Miss Lilian S., F.L.S. 22 South-street, Thurloe-square, S.W.
 1902. †Gibson, Andrew. 14 Cliftonville-avenue, Belfast.
 1901. †Gibson, Professor George A., M.A. 8 Sandyford-place, Glasgow.
 1876. *Gibson, George Alexander, M.D., D.Sc., LL.D., F.R.S.E. 3 Drumsheugh-gardens, Edinburgh.
 1904. *Gibson, Mrs. Margaret D., LL.D. Castle Brae, Chesterton-lane, Cambridge.
 1896. †GIBSON, R. J. HARVEY, M.A., F.R.S.E., Professor of Botany in the University of Liverpool.
 1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.

Year of
Election.

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. (Pres. F, 1887, 1901.) Chanctonbury, Hayward's Heath.
 1898. *Gifford, J. William. Oaklands, Chard.
 1883. §Gilbert, Lady. Park View, Englefield Green, Surrey.
 1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
 1895. †GILCHRIST, J. D. F., M.A., Ph.D., B.Sc., F.L.S. Marine Biologist's Office, Department of Agriculture, Cape Town.
 1896. *GILCHRIST, PERCY C., F.R.S., M.Inst.C.E. Baschurch, Shrewsbury.
 1878. †Giles, Oliver. Brynteg, The Crescent, Bromsgrove.
 1871. *GILL, Sir DAVID, K.C.B., LL.D., F.R.S., Hon.F.R.S.E. (PRESIDENT ELECT). 15 Pembridge-gardens, Kensington, W.
 1902. †Gill, James F. 72 Strand-road, Bootle, Liverpool.
 1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
 1893. *Gimingham, Edward. 21 Stamford Hill-mansions, Stamford Hill, N.
 1904. †GINN, S. R., D.L. (Local Sec. 1904.) Brookfield, Trumpington-road, Cambridge.
 1900. †Ginsburg, Benedict W., M.A., LL.D. Cookham, Berks.
 1884. †Girdwood, G. P., M.D. 28 Beaver Hall-terrace, Montreal, Canada.
 1886. *Gisborne, Hartley, M.Can.S.C.E. Caragana Lodge, Ladysmith, Vancouver Island, Canada.
 1850. *Gladstone, George, F.R.G.S. 34 Denmark-villas, Hove, Brighton.
 1883. *Gladstone, Miss. 19 Chepstow-villas, Bayswater, W.
 1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. (Pres. A, 1890 ; Council, 1878-86.) Trinity College, Cambridge.
 1880. *GLANTAWE, Right Hon. Lord. The Grange, Swansea.
 1881. *GLAZEBROOK, R. T., M.A., D.Sc., F.R.S. (Pres. A, 1893 ; Council, 1890-94, 1905-), Director of the National Physical Laboratory. Bushy House, Teddington, Middlesex.
 1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
 Glover, Thomas. 124 Manchester-road, Southport.
 1878. *Godlee, J. Lister. Wakes Colne Place, Essex.
 1880. †GODMAN, F. DU CANE, D.C.L., F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, W.
 1879. †GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. (Pres. E, 1883.) Nore, Godalming.
 1906. §GOLDIE, Sir GEORGE D. T., K.C.M.G., D.C.L., F.R.S. (Pres. E, 1906 ; Council, 1906-) 44 Rutland-gate, S.W.
 1898. †Goldney, F. Bennett, F.S.A. Goodnestone Park, Dover.
 1886. †GOLDSMID, Major-General Sir F. J., K.C.S.I., C.B., F.R.G.S. (Pres. E, 1886.) 29 Phoenix Lodge-mansions, Brook Green, W.
 1899. †GOMME, G. L., F.S.A. 24 Dorset-square, N.W.
 1890. *GONNER, E. C. K., M.A. (Pres. F, 1897), Professor of Political Economy in the University of Liverpool.
 1884. *Goodridge, Richard E. W. Lupton, Michigan, U.S.A.
 1884. †Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
 1905. †GOULD-ADAMS, Major Sir H. J., K.C.M.G. Government House, Bloemfontein, South Africa.
 1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's-mansions, Westminster, S.W.
 1893. †Gordon, Mrs. M. M. Ogilvie, D.Sc. 1 Rubislaw-terrace, Aberdeen.
 1901. †GORST, Right Hon. Sir JOHN E., M.A., K.C., M.P., F.R.S. (Pres. L, 1901.) 21 Victoria-square, S.W.

Year of
Election.

1875. *GOTCH, FRANCIS, M.A., D.Sc., F.R.S. (Pres. I, 1906; Council, 1901-), Professor of Physiology in the University of Oxford. The Lawn, Banbury-road, Oxford.
1881. †Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1901. †GOURLAY, ROBERT. Glasgow.
1901. §Gow, Leonard. Hayston, Kelvinside, Glasgow.
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.
1902. *Graham, William, M.D. District Lunatic Asylum, Belfast.
1875. †GRAHAME, JAMES (Local Sec. 1876). Care of Messrs. Grahame, Crums, & Connal, 34 West George-street, Glasgow.
1904. §Gramont, Comte Arnaud de. 179 Rue de l'Université, Paris.
1896. †Grant, Sir James, K.C.M.G. Ottawa, Canada.
1905. §Grant-Dalton, Alan. Arundel, Rondebosch, Cape Colony.
1905. †Graumann, Harry. P.O. Box 2115, Johannesburg.
1890. †GRAY, ANDREW, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.
1905. †Gray, C. J. P.O. Box 208, Pietermaritzburg, South Africa.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1881. †Gray, Edwin, LL.B. Minster-yard, York.
1903. §Gray, Ernest, M.A., M.P. 99 Grosvenor-road, S.W.
1902. †Gray, G., M.D. Newcastle, Co. Down.
1904. †Gray, Rev. H. B., D.D. The College, Bradfield, Berkshire.
1892. *Gray, James Hunter, M.A., B.Sc. 141 Hopton-road, Streatham, S.W.
1904. †Gray, J. Macfarlane. 4 Ladbroke-crescent, W.
1892. §GRAY, JOHN, B.Sc. 9 Park-hill, Clapham Park, S.W.
1887. †Gray, Joseph W., F.G.S. St. Elmo, Leckhampton-road, Cheltenham.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1901. †Gray, R. W. 7 Orme-court, Bayswater, W.
1873. †Gray, William, M.R.I.A. Glenburn Park, Belfast.
- *GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1872. *Grece, Clair J., LL.D. 146 Station-road, Redhill, Surrey.
1905. †Green, A. F. Sea Point, Cape Colony.
1904. *Green, A. G. 2 Dartmouth-road, Brondesbury, N.W.
1904. §Green, F. W. St. John's College, Cambridge.
1906. §Green, Professor J. A. The University, Sheffield.
1888. §GREEN, J. REYNOLDS, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1902), Professor of Botany to the Pharmaceutical Society of Great Britain. Downing College, Cambridge.
1903. §Green, W. J. 76 Alexandra-road, N.W.
1882. †GREENHILL, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 1 Staple Inn, W.C.
1905. †Greenhill, Henry H. P.O. Box 172, Bloemfontein, South Africa.
1905. †Greenhill, William. 6A George-street, Edinburgh.
1898. *GREENLY, EDWARD. Achnashean, near Bangor, North Wales.
1906. §Greenwood, Hamar, M.P. National Liberal Club, Whitehall-place, S.W.
1894. *GREGORY, J. WALTER, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.
1896. *Gregory, Professor R. A., F.R.A.S. Dell Quay House, near Chichester.

Year of
Election.

1904. *Gregory, R. P. St. John's College, Cambridge.
 1881. †Gregson, William, F.G.S. Gainford, Darlington.
 1836. Griffin, S. F. Albion Tin Works, York-road, N.
 1894. *Griffith, C. L. T., Assoc.M.Inst.C.E. Flambards, Harrow.
 1884. †GRIFFITHS, E. H., M.A., D.Sc., F.R.S. (Pres. A, 1906), Principal
 of University College, Cardiff.
 1884. †Griffiths, Mrs. University College, Cardiff.
 1903. †Griffiths, Thomas, J.P. 101 Manchester-road, Southport.
 1888. *Grimshaw, James Walter, M.Inst.C.E. 5 Ilchester-gardens, Bays-
 water, W.
 1894. †GROOM, Professor P., M.A., F.L.S. Hollywood, Egham, Surrey.
 1894. †Groom, T. T., M.A., D.Sc., F.G.S., Professor of Geology in the
 University of Birmingham.
 1896. †Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
 1904. †Grosvenor, G. H. New College, Oxford.
 1869. †GRUBB, Sir HOWARD, F.R.S., F.R.A.S. Rockdale, Orwell-road,
 Rathgar, Dublin.
 1897. †Grünbaum, A. S., M.A., M.D. 45 Ladbroke-grove, W.
 1887. †GUILLEMARD, F. H. H., M.A., M.D. The Mill House, Trumpington,
 Cambridge.
 Guinness, Henry. 17 College-green, Dublin.
 1842. Guinness, Richard Seymour. 17 College-green, Dublin.
 1905. *Gunn, Donald. Royal Societies Club, St. James's-street, S.W.
 1866. †GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., F.L.S.,
 F.Z.S. (Pres. D, 1880.) 22 Lichfield-road, Kew, Surrey.
 1894. †Günther, R. T. Magdalen College, Oxford.
 1880. §Guppy, John J. Ivy-place, High-street, Swansea.
 1904. §Gurney, Eustace. Sprowston Hall, Norwich.
 1902. *Gurney, Robert. Ingham Old Hall, Stalham, Norfolk.
 1904. §Guttman, Leo F., Ph.D. 18 Aberdare-gardens, N.W.
 1905. §Hacker, Rev. W. J. 217 Chapel-street, Pietermaritzburg, South
 Africa.
 1881. *HADDON, ALFRED CORT, M.A., D.Sc., F.R.S., F.Z.S. (Pres. H, 1902,
 1905; Council, 1902-) Inisfail, Hills-road, Cambridge.
 1905. †Haddon, Miss. Inisfail, Hills-road, Cambridge.
 1888. *Hadfield, R. A., M.Inst.C.E. Parkhead House, Sheffield.
 1905. †Hahn, Professor P. D., M.A., Ph.D. York House, Gardens, Cape
 Town.
 1906. §Hake, George W. Oxford, Ohio, U.S.A.
 1899. †HALL, A. D., M.A., Director of the Rothamsted Experimental
 Station, Harpenden, Herts.
 1903. †HALL, E. MARSHALL, K.C., M.P. 75 Cambridge-terrace, W.
 1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
 1883. *Hall, Miss Emily. 17 Belmont-street, Southport.
 1854. *HALL, HUGH FERGIE, F.G.S. Cissbury Court, West Worthing,
 Sussex.
 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.
 1884. †Hall, Thomas Proctor. School of Practical Science, Toronto,
 Canada.
 1891. *Hallett, George. 13 Station-road, Penarth.
 1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
 1888. §HALLIBURTON, W. D., M.D., LL.D., F.R.S. (Pres. I, 1902; Council,
 1897-1903), Professor of Physiology in King's College, London.
 Church Cottage, 17 Marylebone-road, N.W.

Year of
Election.

1905. †Halliburton, Mrs. Church Cottage, 17 Marylebone-road, N.W.
 1904. *Hallidie, A. H. S. Avondale, Chesterfield-road, Eastbourne.
 1858. *Hambly, Charles Hambly Burbridge, F.G.S. Fairley, Weston, Bath.
 1904. *Hamel de Manin, Anna Countess de. 35 Circus-road, N.W.
 1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
 1906. §Hamill, John Molyneux, M.A., M.B. 14 South-parade, Chiswick.
 1906. §Hamilton, Charles I. 88 Twyford-avenue, Acton.
 1885. †Hamilton, David James. 35 Queen's-road, Aberdeen.
 1902. †HAMILTON, Rev. T., D.D. Queen's College, Belfast.
 1905. †Hammersley-Heenan, R. H., M.Inst.C.E. Harbour Board Offices, Cape Town.
 1905. §Hammond, Miss Edith. High Dene, Woldingham, Surrey.
 1881. *Hammond, Robert, M.Inst.C.E. 64 Victoria-street, Westminster, S.W.
 1899. *Hanbury, Daniel. Lenqua da Cà, Alassio, Italy.
 1905. *Hancock, Strangman. Plas Uchaf, Abergele, North Wales.
 1890. †Hankin, Ernest Hanbury. St. John's College, Cambridge.
 1894. §Hannah, Robert, F.G.S. 82 Addison-road, W.
 1886. §Hansford, Charles, J.P. Englefield House, Dorchester.
 1906. §Hanson, David. Salterlee, Halifax, Yorkshire.
 1904. §Hanson, E. K. University College, Reading.
 1902. †Harbison, Adam, B.A. 5 Ravenhill-terrace, Ravenhill-road, Belfast.
 1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., V.P.C.S. (GEN. SEC. 1883-97; Pres. B, 1875; Council, 1881-83.) St. Clare, Ryde, Isle of Wight.
 1890. *HARCOURT, L. F. VERNON, M.A., M.Inst.C.E. (Pres G, 1895; Council, 1895-1901.) 6 Queen Anne's-gate, S.W.
 1886. *Hardcastle, Colonel Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
 1902. *HARDCASTLE, Miss FRANCES. 25 Boundary-road, N.W.
 1903. *Hardcastle, J. Alfred. The Dial House, Crowthorne, Berkshire.
 1892. *HARDEN, ARTHUR, Ph.D., M.Sc. Lister Institute of Preventive Medicine, Chelsea-gardens, Grosvenor-road, S.W.
 1905. §Hardie, Miss Mabel, M.B. High-lane, viâ Stockport.
 1877. †Harding, Stephen. Bower Ashton, Clifton, Bristol.
 1894. †Hardman, S. C. 120 Lord-street, Southport.
 1883. †Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
 1881. †Hargrove, William Wallace. St. Mary's, Bootham, York.
 1890. *HARKER, ALFRED, M.A., F.R.S., F.G.S. St. John's College, Cambridge.
 1896. †Harker, Dr. John Allen. National Physical Laboratory, Bushy House, Teddington.
 1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
 1905. †Harland, H. C. P.O. Box 1024, Johannesburg.
 1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
 1883. *Harley, Miss Clara. Rosslyn, Westbourne-road, Forest-hill, S.E.
 1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest-hill, S.E.
 1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
 1881. *HARMER, SIDNEY F., M.A., D.Sc., F.R.S. King's College, Cambridge.
 1906. §Harper, J. B. 16 St. George's-place, York.
 1884. †Harrington, B. J., B.A., Ph.D., F.G.S., Professor of Chemistry and Mineralogy in McGill University, Montreal. University-street, Montreal, Canada.

Year of
Election.

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.
 1903. †Harris, Robert, M.B. 18 Duke-street, Southport.
 1904. §HARRISON, Frank L. 83 Clarkehouse-road, Sheffield.
 1904. †Harrison, H. Spencer. The Horniman Museum, Forest-hill, S.E.
 1892. †HARRISON, JOHN (Local Sec. 1892). Rockville, Napier-road, Edinburgh.
 1870. †HARRISON, REGINALD, F.R.C.S. (Local Sec. 1870.) 6. Lower Berkeley-street, Portman-square, W.
 1892. †Harrison, Rev. S. N. Ramsey, Isle of Man.
 1901. *Harrison, W. E. 15 Lansdowne-road, Handsworth, Staffordshire.
 1886. †Harrison, W. Jerome, F.G.S. Science Laboratory, Icknield-street Council School, Birmingham.
 1885. †HART, Colonel C. J. (Local Sec. 1886.) Highfield Gate, Edgbaston, Birmingham.
 1876. *Hart, Thomas. Brookland, Blackburn.
 1903. *Hart, Thomas Clifford. Brookland, Blackburn.
 1875. †Hart, W. E. Kilderry, near Londonderry.
 1893. *HARTLAND, E. SIDNEY, F.S.A. (Pres. H, 1906 ; Council, 1906- .) Highgarth, Gloucester.
 1905. †Hartland, Miss. Highgarth, Gloucester.
 1871. *HARTLEY, WALTER NOEL, D.Sc., F.R.S., F.R.S.E., F.C.S. (Pres. B, 1903), Professor of Chemistry in the Royal College of Science, Dublin. 36 Waterloo-road, Dublin.
 1886. *HARTOG, Professor M. M., D.Sc. Queen's College, Cork.
 1887. †HARTOG, P. J., B.Sc. University of London, South Kensington, S.W.
 1905. †Harvey-Hogan, J. P.O. Box 1277, Johannesburg.
 1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.
 1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
 1893. §Haslam, Lewis. 44 Evelyn-gardens, S.W.
 1903. *Hastie, Miss J. A. Care of Messrs. Street & Co., 30 Cornhill, E.C.
 1903. §Hastie, William. 20 Elswick-row, Newcastle-on-Tyne.
 1904. †Hastings, G. 15 Oak-lane, Bradford, Yorkshire.
 1875. *HASTINGS, G. W. (Pres. F, 1880.) Chapel House, Chipping Norton.
 1903. §Hastings, W. G. W. Chapel House, Chipping Norton.
 1889. †Hatch, F. H., Ph.D., F.G.S. P.O. Box 1030, Johannesburg.
 1903. †Hathaway, Herbert G. 45 High-street, Bridgnorth, Salop.
 1904. *Haughton, W. T. H. The Highlands, Great Barford, St. Neots.
 1904. †Havilland, Hugh de. Eton College, Windsor.
 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. (Council, 1881-87.) 22 Down-street, W., and 33 Great George-street, S.W.
 1897. §HAWKSLEY, CHARLES, M.Inst.C.E., F.G.S. (Pres. G, 1903 ; Council, 1902- .) 30 Great George-street, S.W.
 1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
 1861. *HAY, Admiral the Right Hon. Sir JOHN C. D., Bart., G.C.B., D.C.L., F.R.S. 108 St. George's-square, S.W.
 1885. *HAYCROFT, JOHN BERRY, M.D., B.Sc., F.R.S.E., Professor of Physiology in University College, Cardiff.
 1900. §Hayden, H. H., B.A., F.G.S. Geological Survey, Calcutta, India.
 1903. *Haydock, Arthur. 197 Preston New-road, Blackburn.
 1903. §Hayward, Joseph William, M.Sc. 29 Deodar-road, Putney, S.W.

Year of
Election.

1896. *Haywood, Lieut.-Colonel A. G. Rearsby, Merrilocks-road, Blundellsands.
1879. *Hazelhurst, George S. The Grange, Rockferry.
1883. †Heape, Joseph R. Glebe House, Rochdale.
1882. *Heape, Walter, M.A., F.R.S. Heyrour, Chaucer-road, Cambridge.
1902. †Heath, J. W. Royal Institution, Albemarle-street, W.
1902. §Heathorn, Captain T. B., R.A. 10 Wilton-place, Knightsbridge, S.W.
1883. †Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1892. *HEATON, WILLIAM H., M.A. (Local Sec. 1893), Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West. 12 Tring-avenue, Ealing, W.
1888. *Heawood, Edward, M.A. Briarfield, Church-hill, Merstham, Surrey.
1888. *Heawood, Percy J., Lecturer in Mathematics in 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. 10 Cranley-place, South Kensington, S.W.
1881. *HELE-SHAW, H. S., LL.D., F.R.S., M.Inst.C.E. 64 Victoria-street, S.W.
1901. *Heller, W. M., B.Sc. 40 Upper Sackville-street, Dublin.
1905. †Hellman, Hugo. Rand Club, Johannesburg.
1887. §Hembry, Frederick William, F.R.M.S. Langford, Sidecup, Kent.
1899. †Hemsalech, G. A., D.Sc. The Owens College, Manchester.
1873. *Henderson, A. L. Westmoor Hall, Brimsdown, Middlesex.
1901. †Henderson, Rev. Andrew, LL.D. Castle Head, Paisley.
1905. *Henderson, Andrew. 17 Belhaven-terrace, Glasgow.
1905. *Henderson, Miss Catharine. 17 Belhaven-terrace, Glasgow.
1891. *HENDERSON, G. G., D.Sc., M.A., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College, Glasgow.
1905. §Henderson, Mrs. Technical College, Glasgow.
1906. §Henderson, J. B., D.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1880. *Henderson, Vice-Admiral W. H., R.N. 12 Vicarage-gardens, Campden Hill, W.
1904. *Hendrick, James. Marischal College, Aberdeen.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S. (Pres. A, 1883; Council, 1883-89), 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.
1906. §Henry, Dr. T. A. Imperial Institute, S.W.
1892. †HEPBURN, DAVID, M.D., F.R.S.E., Professor of Anatomy in University College, Cardiff.
1904. §Hepworth, Commander M. W. C., C.B., R.N.R. Meteorological Office, Victoria-street, S.W.
1892. *HERBERTSON, ANDREW J., Ph.D., F.R.S.E., F.R.G.S. 4 Broad-street, Oxford.
1902. †Herdman, G. W., B.Sc.. Assoc.M.Inst.C.E. Irrigation and Water Supply Department, Pretoria.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., Pres.L.S.(GENERAL SECRETARY, 1903-; Pres. D, 1895; Council, 1894-1900; Local Sec. 1896), Professor of Natural History in the University of Liverpool. Croxteth Lodge, Sefton Park, Liverpool.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.

Year of
Election.

1875. †HEREFORD, The Right Rev. JOHN PERCIVAL, D.D., LL.D., Lord Bishop of. (Pres. L, 1904.) The Palace, Hereford.
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.
1900. *Herschel, J. C. W. 92 Woodstock-road, Oxford.
1905. †Hervey, Miss Mary F. S. 22 Morpeth-mansions, S.W.
1903. *HESKETH, CHARLES H. B., M.A. The Rookery, North Meols, Southport.
1895. §Hesketh, James. Scarisbrick Avenue-buildings, 107 Lord-street, Southport.
1905. †Hewat, M. L., M.D. Mowbray, near Cape Town, South Africa.
1894. †HEWETSON, G. H. (Local Sec. 1896.) 39 Henley-road, Ipswich.
1894. †Hewins, W. A. S., M.A., F.S.S. The Rowans, Putney Lower Common. S.W.
1896. §Hewitt, Dr. David Basil. Oakleigh, Northwich, Cheshire.
1903. †Hewitt, E. G. W. 87 Princess-road, Moss Side, Manchester.
1903. †Hewitt, John Theodore, M.A., D.Sc., Ph.D. 8 Montpelier-road, Twickenham.
1882. *HEYCOCK, CHARLES T., M.A., F.R.S. King's College, Cambridge.
1883. †Heyes, Rev. John Frederick, M.A., F.R.G.S. 27 Arkwright-street, Bolton.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1901. *Heys, Z. John. Stonehouse, Barrhead, N.B.
1886. †HEYWOOD, HENRY, J.P. Witla Court, near Cardiff.
1898. †Hicks, Henry B. 44 Pembroke-road, Clifton, Bristol.
1877. §HICKS, W. M., M.A., D.Sc., F.R.S. (Pres. A, 1895), Professor of Physics in the University of Sheffield. Leamhurst, Ivy Park-road, Sheffield.
1886. †Hicks, Mrs. W. M. Leamhurst, Ivy Park-road, Sheffield.
1887. *HICKSON, SYDNEY J., M.A., D.Sc., F.R.S. (Pres. D, 1903), Professor of Zoology in Victoria University, Manchester.
1864. *HIERN, W. P., M.A., F.R.S. The Castle, Barnstaple.
1891. †HIGGS, HENRY, LL.B., F.S.S. (Pres. F, 1899; Council, 1904-06). H.M. Treasury, Whitehall, S.W.
1907. §HILEY, E. V., Town Clerk. (Local Sec. 1907.) Town Hall, Leicester.
1885. *HILL, ALEXANDER, M.A., M.D. Downing College, Cambridge.
1903. *Hill, Arthur W. King's College, Cambridge.
1906. §Hill, Charles A. 13 Rodney-street, Liverpool.
1881. *HILL, Rev. EDWIN, M.A. The Rectory, Cockfield, Bury St. Edmunds.
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. 80 Harvard-court, West End-lanc, N.W.
1885. *HILLHOUSE, WILLIAM, M.A., F.L.S., Professor of Botany in the University of Birmingham. 43 Calthorpe-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, near Bedford.
1903. *Hilton, Harold. 2 Bryn Teg-terrace, Bangor, North Wales.
1903. §HIND, Dr. WHEELTON, F.G.S. Roxeth House, Stoke-on-Trent.
1870. †HINDE, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.

Year of
Election.

1898. §Hinds, Henry. 57 Queen-street, Ramsgate.
 1906. *Hingston, Miss A. Clarence Cottage, Clare-road, Cambridge.
 1900. §Hinks, Arthur R., M.A. The Observatory, Cambridge.
 1903. *Himmers, Edward. Glentwood, South Downs-drive, Hale, Cheshire.
 1906. §Hitchcock, Dr. C. K. Bootham Park, York.
 1899. §Hobday, Henry. Hazelwood, Crabble Hill, Dover.
 1887. *Hobson, Bernard, M.Sc., F.G.S. Thornton, Didsbury, near Manchester.
 1883. †Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, W.
 1904. §Hobson, Ernest William, Sc.D., F.R.S. The Gables, Mount Pleasant, Cambridge.
 1877. †Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
 1863. *HODGKIN, THOMAS, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
 1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology in the Victoria University, Manchester. 18 St. John-street, Manchester.
 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 Glenluce-road, Blackheath, S.E.
 1905. §Hodgson, Ven. Archdeacon R. The Rectory, Wolverhampton.
 1898. †Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
 1904. §Hodson, F. Bedale's School, Petersfield, Hampshire.
 1904. †Hogarth, D. G., M.A. Chapel Meadow, Forest Row, Sussex.
 1894. †Hogg, A. F., M.A. 13 Victoria-road, Darlington.
 1883. †Holden, John J. 73 Albert-road, Southport.
 1887. *Holder, Henry William, M.A. Sheet, near Petersfield.
 1900. †HOLDICH, Colonel Sir THOMAS H., R.E., K.C.B., K.C.I.E., F.R.G.S. (Pres. E, 1902.) 41 Courtfield-road, S.W.
 1887. *Holdsworth, C. J. Fernhill, Alderley Edge, Cheshire.
 1904. §Holland, Charles E. 9 Downing-place, Cambridge.
 1903. §Holland, J. L., B.A. 72 Kingsley Park-terrace, Northampton.
 1896. †Holland, Mrs. Lowfields House, Hooton, Cheshire.
 1898. †Holland, Thomas H., F.R.S., F.G.S. Geological Survey Office, Calcutta.
 1889. †Holländer, Bernard, M.D. 35A Welbeck-street, W.
 1906. *Hollingworth, Miss. St. Cuthbert's Manor, Bedford.
 1905. †Hollway, H. C. Schunke. Plaisir de Merle, P.O. Simondium, via Paarl, South Africa.
 1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
 1866. *Holmes, Charles. 36 Buckingham-mansions, West End-lane, N.W.
 1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.
 1903. *Holt, Alfred, jun. Crofton, Aigburth, Liverpool.
 1875. *Hood, John. Chesterton, Cirencester.
 1904. §Hooke, Rev. D. Burford. Bonchurch Lodge, Barnet.
 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. (PRESIDENT, 1868; Pres. E, 1881; Council, 1866-67.) The Camp, Sunningdale, Berkshire.
 1892. †HOOKER, REGINALD H., M.A. 3 Gray's Inn-place, W.C.
 1865. *Hooper, John P. Deepdene, Streatham Common, S.W.
 1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
 1904. †Hopewell-Smith, A., M.R.C.S. 37 Park-street, Grosvenor-square, S.W.
 1905. *Hopkins, Charles[†]Hadley.[‡] Junior Constitutional Club, 101 Piccadilly, W.

- Year of Election.
1901. *Hopkinson, Bertram, M.A. Adams-road, Cambridge.
1884. *HOPKINSON, CHARLES (Local Sec. 1887). The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Ferns, Alderley Edge, Cheshire.
1871. *HOPKINSON, JOHN, Assoc.M.Inst.C.E., F.L.S., F.G.S., F.R.Met.Soc. 84 New Bond-street, W. ; and Weetwood, Watford.
1905. †Hopkinson, Mrs. John. Holmwood, Wimbledon Common, S.W.
1898. *Hornby, R., M.A. Haileybury College, Hertford.
1885. †HORNE, JOHN, LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1901.) Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1903. §Horne, William, F.G.S. Leyburn, Yorkshire.
1902. †Horner, John. Chelsea, Antrim-road, Belfast.
1905. *Horsburgh, E. M., M.A., B.Sc., Lecturer in Technical Mathematics in the University of Edinburgh.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. †Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *HORSLEY, Sir VICTOR A. H., LL.D., B.Sc., F.R.S., F.R.C.S. (Council, 1893-98.) 25 Cavendish-square, W.
1884. *Hotblack, G. S. Brundall, Norwich.
1899. †Hotblack, J. T., F.G.S. 45 Newmarket-road, Norwich.
1859. †Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1906. *Hough, Miss Ethel M. Codsall Wood, near Wolverhampton.
1896. *Hough, S. S., M.A., F.R.S., F.R.A.S., His Majesty's Astronomer at the Cape of Good Hope. Royal Observatory, Cape Town.
1905. §Houghting, A. G. L. Glenelg, Musgrave-road, Durban, Natal.
1905. †Houseman, C. L. P.O. Box 149, Johannesburg.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, S.E.
1904. *Howard, Mrs. G. L. C. Agricultural Research Institute, Pusa, Bengal, India.
1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.
1901. §Howarth, E. Public Museum, Weston Park, Sheffield.
1903. *Howarth, James H., F.G.S. Somerley, Rawson-avenue, Halifax.
1905. †Howick, Dr. W. P.O. Box 503, Johannesburg.
1901. †Howie, Robert Y. 3 Greenlaw-avenue, Paisley.
1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. 7 Prince's-buildings, Clifton, Bristol.
1863. †HOWORTH, Sir H. H., K.C.I.E., D.C.L., F.R.S., F.S.A. 30 Colling-ham-place, Cromwell-road, S.W.
1887. §HOYLE, WILLIAM E., M.A., D.Sc. Victoria University, Manchester.
1903. †Hübner, Julius. Ash Villa, Cheadle Hulme, Cheshire.
1898. §HUDLESTON, W. H., M.A., F.R.S., F.G.S. (Pres. C, 1898.) 8 Stanhope-gardens, S.W.
1898. †Hudson, Mrs. Sunny Bank, Egerton, Huddersfield.
1867. *HUDSON, WILLIAM H. H., M.A. 60 Altenburg-gardens, Clapham Common, S.W.
1858. *HUGGINS, Sir WILLIAM, K.C.B., D.C.L., LL.D., F.R.S., F.R.A.S. (PRESIDENT, 1891 ; Council, 1868-74, 1876-84.) 90 Upper Tulse-hill, S.W.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1868. §HUGHES, T. M'K., M.A., F.R.S., F.G.S. (Council, 1879-86), Woodwardian Professor of Geology in the University of Cambridge. Ravensworth, Brooklands-avenue, Cambridge.
1867. †HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. (Pres. C, 1874.) 14 Stanley-gardens, Notting Hill, W.
1903. †Hulton, Campbell G. Palace Hotel, Southport.

Year of
Election.

1905. §Hume, D. G. W. P.O. Box 1132, Johannesburg.
1901. †Hume, John H. Toronto, Canada ; and 63 Bridgegate, Irvine.
1890. †Humphrey, Frank W. 63 Prince's-gate, S.W.
1904. *Humphreys, Alexander C., Sc.D., LL.D., President of the Stevens Institute of Technology, Hoboken, New Jersey, U.S.A.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur, Southwood, Torquay.
1881. †Hunter, F. W. 16 Old Elvet, Durham.
1889. †Hunter, Mrs. F. W. 16 Old Elvet, Durham.
1901. *Hunter, William. Evirallan, Stirling.
1903. †Hurst, Charles C., F.L.S. Burbage, Hinckley.
1882. *Hurst, Walter, M.D., B.Sc. 210 Seventh-avenue, San Francisco, U.S.A.
1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.
1905. †Hutcheon, Duncan, M.R.C.V.S., Department of Agriculture, Cape Town.
1894. *HUTCHINSON, A., M.A., Ph.D. (Local Sec. 1904.) Pembroke College, Cambridge.
1903. §Hutchinson, Rev. H. N. 94 Fellows-road, N.W. 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.
1901. *Hutton, R. S., M.Sc. The Victoria University, Manchester.
1883. †Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman, H. H. Francis. 27 Pembroke-square, W.
1883. §Idris, T. H. W. 110 Pratt-street, Camden Town, N.W. Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1906. §Iliffe, J. W. Oak Tower, Uppertorpe, Sheffield.
1885. †Jim Thurn, Sir Everard F., C.B., K.C.M.G. Colombo, Ceylon.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1905. §Ingham, W. Engineer's Office, Sand Rive, Uitenhage.
1893. †Ingle, Herbert. Department of Agriculture, Pretoria.
1901. †INGLIS, JOHN, LL.D. 4 Prince's-terrace, Dowanhill, Glasgow.
1852. †INGRAM, J. K., LL.D., M.R.I.A. (Pres. F, 1878), Senior Lecturer in the University of Dublin. 2 Wellington-road, Dublin.
1905. §Innes, R. T. A., F.R.A.S. Meteorological Observatory, Johannesburg.
1901. *Ionides, Stephen A. 23 Second-avenue, Hove, Brighton.
1882. §IRVING, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1903. †Irving, W. B. 27 Park-road, Southport.
1905. †Iwasaki, Koyata. Pembroke College, Cambridge.
1876. *JACK, WILLIAM, LL.D., Professor of Mathematics in the University of Glasgow. 10 The University, Glasgow.
1901. §Jacks, William, LL.D. The Gart, Callander.
1883. *Jackson, Professor A. H., B.Sc. 349 Collins-street, Melbourne, Australia.
1903. §Jackson, C. S. 96 Herbert-road, Woolwich, S.E.
1883. *Jackson, F. J. 35 Leyland-road, Southport.

Year of
Election.

1883. †Jackson, Mrs. F. J. 35 Leyland-road, Southport.
 1874. *Jackson, Frederick Arthur. Belmont, Somenos, Vancouver Island, B.C., Canada.
 1899. †Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
 1897. §Jackson, James, F.R.Met.Soc. Seabank, Girvan, N.B.
 1906. *Jackson, James Thomas, M.A. Engineering School, Trinity College, Dublin.
 1898. *Jackson, Sir John. 51 Victoria-street, S.W.
 1869. †Jackson, Moses, J.P. The Orchards, Whitechurch, Hants.
 1905. †Jacobsohn, Lewis B. Lloyd's-buildings, 58 Burg-street, Cape Town.
 1905. †Jacobsohn, Sydney Samuel. Lloyd's-buildings, 58 Burg-street, Cape Town.
 1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
 1905. *Jaffé, Arthur, B.A. Strandtown, Belfast.
 1874. *Jaffé, John. Villa Jaffé, 38 Promenade des Anglais, Nice, France.
 1905. †Jagger, J. W. St. George's-street, Cape Town.
 1906. §Jalland, W. H. Museum-street, York.
 1891. *James, Charles Henry, J.P. 64 Park-place, Cardiff.
 1891. *James, Charles Russell. 5 Raymond-buildings, Gray's Inn, W.C.
 1904. §James, Thomas Campbell. University College, Aberystwyth.
 1905. †Jameson, Adam. Office of the Commissioner of Lands, Pretoria.
 1896. *Jameson, H. Lyster, M.A., Ph.D. Transvaal Technical Institute, Johannesburg.
 1881. †Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
 1859. *Jamieson, Thomas F., LL.D., F.G.S. Ellon, Aberdeenshire.
 1889. *JAPP, F. R., M.A., Ph.D., LL.D., F.R.S. (Pres. B, 1898), Professor of Chemistry in the University of Aberdeen.
 1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
 1903. †JARRATT, J. ERNEST. (Local Sec. 1903.) 10 Cambridge-road, Southport.
 1904. *Jeans, J. H., F.R.S. Princeton, New Jersey, U.S.A.
 1897. †Jeffrey, E. C., B.A. The University, Toronto, Canada.
 1903. †Jenkinson, J. W. The Museum, Oxford.
 1904. †Jenkinson, W. W. 6 Moorgate-street, E.C.
 1893. §Jennings, G. E. Glen Helen, Narborough-road, Leicester.
 1905. §Jennings, Sydney. P.O. Box, 149 Johannesburg.
 1905. §Jerome, Charles. P.O. Box 83, Johannesburg.
 1887. †JERVIS-SMITH, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.
 Jessop, William. Overton Hall, Ashover, Chesterfield.
 1900. *Jevons, H. Stanley. Llanishen, near Cardiff.
 1905. §Jeyes, Miss Gertrude, B.A. Berrymead, 6 Lichfield road, Kew Gardens.
 1905. †Jobson, J. B. P.O. Box 3341, Johannesburg.
 1884. †JOHNSON, ALEXANDER, M.A., LL.D., Professor of Mathematics in McGill University, Montreal, 5 Prince of Wales-terrace, Montreal, Canada.
 1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
 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.
 1902. *Johnson, Rev. W., B.A., B.Sc. Archbishop Holgate's Grammar School, York.
 1898. *Johnson, W. Claude, M.Inst.C.E. Broadstone, Coleman's Hatch, Sussex.
 1899. §Johnston, Colonel Sir Duncan A., K.C.M.G., C.B., R.E. Ordnance Survey, Southampton.

- Year of Election.
1883. †JOHNSTON, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. 27 Chester-terrace, Regent's-park, N.W.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. †JOHNSTON-LAVIS, H. J., M.D., F.G.S. Beaulieu, Alpes Maritimes, France.
1888. †JOLY, JOHN, M.A., D.Sc., F.R.S., F.G.S., Professor of Geology and Mineralogy in the University of Dublin. Geological Department, Trinity College, Dublin.
1887. †Jones, D. E., B.Sc. Inglewood, Four Oaks, Sutton Coldfield.
1904. §Jones, Miss E. E. Constance. Girton College, Cambridge.
1890. §JONES, Rev. EDWARD, F.G.S. Primrose Cottage, Emsbay, Skipton.
1896. †Jones, E. Taylor, D.Sc. University College, Bangor.
1903. §Jones, Evan. Ty-Mawr, Aberdare.
1887. †Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev. G. HARTWELL, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge-road, Waterloo, Liverpool.
1903. *JONES, H. O., M.A. Clare College, Cambridge.
1901. §Jones, R. E., J.P. Oakley Grange, Shrewsbury.
1902. †Jones, R. M., M.A. Royal Academical Institution, Belfast.
1905. §Jones, Miss Parnell. The Rectory, Llanddewi Skirrid, Abergavenny, Monmouthshire.
1860. †JONES, THOMAS RUPERT, F.R.S., F.G.S. (Pres. C, 1891.) Penbryn, Chesham Bois-lane, Chesham, Bucks.
1875. *Jose, J. E. Ethersall, Tarbock-road, Huyton, Lancashire.
1883. †Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. †Joyce, Hon. Mrs. St. John's Croft, Winchester.
1905. §Judd, Miss Hilda M., B.Sc. Berrymead, 6 Lichfield-road, Kew.
1870. †JUDD, JOHN WESLEY, C.B., LL.D., F.R.S., F.G.S. (Pres. C, 1885; Council, 1886-92.) Orford Lodge, 30 Cumberland-road, Kew.
1903. §Julian, Henry Forbes. Redholme, Braddon's Hill-road, Torquay.
1894. §Julian, Mrs. Forbes. Redholme, Braddon's Hill-road, Torquay.
1905. §Juritz, C. F., M.A., F.I.C. Government Analytical Laboratory, Parliament-street, Cape Town.
1888. †Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. 3 Lindenallee, Westend, Berlin.
1904. †Kayser, Professor H. The University, Bonn, Germany.
1878. *Kelland, W. H. 80 Lothian-road, S.W.
1902. *Kelly, William J., J.P. 25 Oxford-street, Belfast.
1885. §KELTIE, J. SCOTT, LL.D., Sec. R.G.S., F.S.S. (Pres. E, 1897; Council, 1898-1904.) 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. (PRESIDENT, 1871; Pres. A, 1852, 1867, 1876, 1881, 1884.) Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.
1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.
1887. †Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1898. *Kemp, John T., M.A. 4 Cotham-grove, Bristol.
- . †Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.

Year of
Election.

1891. §KENDALL, PERCY F., M.Sc., F.G.S., Professor of Geology in the University of Leeds.
1875. †KENNEDY, Sir ALEXANDER B. W., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1894.) 1 Queen Anne-street, Cavendish-square, W.
1906. §Kennedy, Alfred Joseph, F.R.G.S. Care of Williams Deacon's Bank, Ltd., 2 Cockspur-street, S.W.
1897. §Kennedy, George, M.A., LL.D., K.C. Crown Lands Department, Toronto, Canada.
1906. §Kennedy, Robert Sinclair. Glengall Ironworks, Millwall, E.
1905. *Kennerley, W. R. P.O. Box 158, Pretoria.
1893. §KENT, A. F. STANLEY, M.A., F.L.S., F.G.S., Professor of Physiology in University College, Bristol.
1901. †Kent, G. 16 Premier-road, Nottingham.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1883. †KERR, Rev. JOHN, LL.D., F.R.S. Free Church Training College, 113 Hill-street, Glasgow.
1892. †KERR, J. GRAHAM, M.A., Professor of Natural History in the University, Glasgow.
1889. †Kerry, W. H. R. The Sycamores, Windermere.
1869. *Kesselmeyer, Charles Augustus. Rose Villa, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Elysée Villa, Manchester-road, Altrincham, Cheshire.
1903. §Kewley, James. Care of Nederlandsch Indische Industrie en Handel, Maatschappij, Balek Pappan, Dutch Borneo.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1905. †Kidd, Professor A. Stanley. Rhodes University College, Grahams-town, Cape Colony.
1902. §Kidd, George. Greenhaven, Malone Park, Belfast.
1906. §Kidner, Henry, F.G.S. 78 Gladstone-road, Watford.
1886. §KIDSTON, ROBERT, F.R.S., F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1901. *Kiep, J. N. 4 Hughenden-terrace, Kelvinside, Glasgow.
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. Dame Armstrong House, Harrow.
1905. §Kincaid, Major-General W. Care of Messrs. Alexander, Fletcher, & Co., 2 St. Helen's-place, Bishopsgate-street, E.C.
1905. §Kincaid, Mrs. Care of Messrs. Alexander, Fletcher, & Co., 2 St. Helen's-place, Bishopsgate-street, E.C.
1875. *KINCH, EDWARD, F.C.S. Royal Agricultural College, Cirencester.
1872. *King, Mrs. E. M. Melrose, Alachua, Co. Florida, U.S.A.
1888. *King, E. Powell. Wainsford, Lymington, Hants.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1899. †KING, Sir GEORGE, K.C.I.E., F.R.S. (Pres. K, 1899.) Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1883. *King, John Godwin. Stonelands, West Hoathly.
1883. *King, Joseph. Sandhouse, Witley, Godalming.
1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1870. †King, William, M.Inst.C.E. 5 Beach-lawn, Waterloo, Liverpool.
1903. §Kingsford, H. S., M.A. Anthropological Institute, 3 Hanover-square, W.
1900. †KIPPING, Professor F. STANLEY, D.Sc., Ph.D., F.R.S. University College, Nottingham.

- Year of
Election.
1899. *Kirby, Miss C. F. 74 Kensington Park-road, W.
1905. §Kirkby, Reginald G. P.O. Box 7, Pietermaritzburg, Natal.
1890. *KITSON, Right Hon. Sir JAMES, Bart., M.P. Gledhow Hall, Leeds.
1901. §Kitto, Edward. The Observatory, Falmouth.
1886. †Knight, Captain J. M., F.G.S. Bushwood, Wanstead, Essex.
1905. §Knightley, Lady, of Fawsley. Fawsley Park, Daventry.
1898. †KNOCKER, Sir E. WOLLASTON, K.C.B. (Local Sec. 1899.) Castle Hill House, Dover.
1888. †KNOTT, Professor CARGILL G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert. Aingarh, Stalybridge, Cheshire.
1887. *Knott, John F. St. Martin's, Hooton, near Chester.
1906. *Knowles, Arthur J., B.A., M.Inst.C.E. New Nile Bridge, Roda Island, Cairo, Egypt.
1874. †Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1903. †Knowlson, J. F. 26 Part-street, Southport.
1902. †KNOX, R. KYLE, LL.D. 1 College-gardens, Belfast.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. †Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1905. †Koenig, J. P.O. Box 272, Cape Town.
1892. †KOHN, CHARLES A., Ph.D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
1890. *Krauss, John Samuel, B.A. Stonycroft, Knutsford-road, Wilmslow, Cheshire.
1888. *Kunz, G. F., M.A., Ph.D. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.
1905. †Lacey, William. Champ d'Or Gold Mining Co., Luipaardsvlei, Transvaal.
1885. *Laing, J. Gerard. 5 Pump-court, Temple, E.C.
1904. †Lake, Philip. St. John's College, Cambridge.
1904. †Lamb, C. G. Ely Villa, Glisson-road, Cambridge.
1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1887. †LAMB, HORACE, M.A., LL.D., D.Sc., F.R.S. (Pres. A, 1904), Professor of Pure Mathematics in the Victoria University, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1903. †Lambert, Joseph. 9 Westmoreland-road, Southport.
1893. *LAMPLUGH, G. W., F.R.S., F.G.S. (Pres. C, 1906.) 13 Beaconsfield-road, St. Albans.
1905. †Lane, Rev. C. A. P.O. Box 326, Johannesburg.
1898. *LANG, WILLIAM H. 61 Gibson-street, Hillhead, Glasgow.
1905. §Lange, John H. Judges' Chambers, Kimberley.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. (Pres. I, 1899; Council, 1904-), Professor of Physiology in the University of Cambridge. Trinity College, Cambridge.
1865. †LANKESTER, E. RAY, M.A., LL.D., D.Sc., F.R.S. (PRESIDENT; Pres. D, 1883; Council, 1889-90, 1894-95, 1900-02), 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.
1885. †LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S. (Pres. C, 1892), Professor of Geology and Physiography in the University of Birmingham. 48 Frederick-road, Edgbaston, Birmingham.
1887. †Larmor, Alexander. Craglands, Helen's Bay, Co. Down.

Year of
Election.

1881. †LARMOR, JOSEPH, M.A., D.Sc., Sec.R.S. (Pres. A, 1900), Lucasian Professor of Mathematics in the University of Cambridge. St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. Longridge, 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.
1900. †Lauder, Alexander, Lecturer in Agricultural Chemistry in the Edinburgh and East of Scotland College of Agriculture, Edinburgh.
1892. †LAURIE, MALCOLM, B.A., D.Sc., F.L.S. School of Medicine, Surgeons' Hall, Edinburgh.
1883. †Laurie, Major-General. Oakfield, Nova Scotia, Canada.
1870. *Law, Channell. Ilsham Dene, Torquay.
1884. †Law, Robert, F.G.S. Fennyroyd Hall, Hipperholme, near Halifax, Yorkshire.
1907. §Lawford, James. (Local Treas. 1907.) London City and Midland Bank, Leicester.
1905. §Lawrence, Miss M. Roedan School, near Brighton.
1888. §Layard, Miss Nina F. Rookwood, Tonnereau-road, Ipswich.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1894. *LEAHY, A. H., M.A., Professor of Mathematics in the University of Sheffield. 92 Ashdell-road, Sheffield.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1905. §Leake, E. O. 5 Harrison-street, Johannesburg.
1901. *Lean, George, B.Sc. 15 Park-terrace, Glasgow.
1904. *Leathem, J. G. St. John's College, Cambridge.
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 Durham College of Science, Newcastle-on-Tyne.
1895. *Ledger, Rev. Edmund. Protea, Doods-road, Reigate.
1905. †Lee, Arthur. 1 Carrowdore-terrace, Main-road, Three Anchor Bay, Cape Town.
1898. †LEE, ARTHUR, J.P. (Local Sec. 1898.) 10 Berkeley-square, Clifton, Bristol.
1896. §Lee, Rev. H. J. Barton. 35 Cross Park-terrace, Heavitree, Exeter.
1894. *Lee, Mrs. W. Ashdown House, Forest Row, Sussex.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.
1905. §Lees, Mrs. A. P. Care of Parr's Bank, York-street, Manchester.
1892. *LEES, CHARLES H., D.Sc., F.R.S., Professor of Physics in the East London College, Mile End. Greenacres, Mayfield-avenue, Woodford Green, Essex.
1886. *Lees, Lawrence W. Old Ivy House, Tettenhall, Wolverhampton.
1906. §Lees, Robert. Victoria-street, Fraserburgh.
1905. †Lees, R. Wilfrid. Pigg's Peak Development Co., Swaziland, South Africa.
- *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.
1906. §Leetham, Sidney. Elm Bank, York.
1881. †LE FEUVRE, J. E. (Local Sec. 1882.) Southampton.
1905. †Legg, W. A. P.O. Box 1621, Cape Town.
1892. †LEHFELDT, ROBERT A. 56 Norfolk-square, W.
1891. †Leigh, W. W. Glyn Bargoed, Treharris, R.S.O., Glamorganshire.
1903. †Leighton, G. R., M.D., F.R.S.E., Professor of Pathology in the Royal Veterinary College, Edinburgh.

Year of
Election.

1906. §Leiper, Robert T., M.B., F.Z.S. London School of Tropical Medicine, Royal Albert Dock, E.
1905. §Leitch, Donald. P.O. Box 1703, Johannesburg.
1882. §Lemon, James, M.Inst.C.E., F.G.S. Lansdowne House, Southampton.
1903. *Lempfort, R. G. K., M.A. Meteorological Office, 63 Victoria-street, S.W.
1902. †Lennox, R. N. Rosebank, Hammersmith, W.
1887. *Leon, John T. Elmwood, Grove-road, Southsea.
1901. §LEONARD, J. H., B.Sc. 28 Talgarth-road, West Kensington, W.
1905. †Leonard, Right Rev. Bishop John. St. Mary's, Cape Town.
1904. †Lepper, Alfred William. 6 Trinity College, Dublin.
1890. *Lester, Joseph Henry, Royal Exchange, Manchester.
1904. *Le Sueur, H. R., D.Sc. Chemical Laboratory, St. Thomas's Hospital, S.E.
1900. †Letts, Professor E. A., D.Sc., F.R.S.E. Queen's College, Belfast.
1896. §Lever, W. H. Thornton Manor, Thornton Hough, Cheshire.
1905. †Levin, Benjamin. P.O. Box 74, Cape Town.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1893. *LEWIS, VIVIAN B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1905. §Lewin, J. B. Duncan's-chambers, Shortmarket-street, Cape Town.
1904. *Lewis, Mrs. Agnes S., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1870. †LEWIS, ALFRED LIONEL. 35 Beddington-gardens, Wallington, Surrey.
1891. †Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.
1905. †Lewis, F. S., M.A. South African Public Library, Cape Town.
1904. †Lewis, Hugh. Glanafrau, Newton, Montgomeryshire.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.
1903. †Lewkowitsch, Dr. J. 71 Priory-road, N.W.
1906. §Liddiard, James Edward, F.R.G.S. Rodborough Grange, Bourne-mouth.
1904. †Link, Charles W. 14 Chichester-road, Croydon.
1898. §Lippincott, R. C. Cann. Over Court, Almondsbury, near Bristol.
1895. *LISTER, The Right Hon. Lord, F.R.C.S., D.C.L., D.Sc., F.R.S. (PRESIDENT, 1896.) 12 Park-crescent, Portland-place, W.
1888. †LISTER, J. J., M.A., F.R.S. (Pres. D, 1906.) St. John's College, Cambridge.
1861. *LIVEING, G. D., M.A., F.R.S. (Pres. B, 1882; Council 1888-95; Local Sec. 1862), 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.
1902. §Llewellyn, Evan. Working Men's Institute and Hall, Blaenavon.
1903. §Lloyd, Godfrey I. H. 8 Claremont-place, Sheffield.
1891. *LLOYD, R. J., M.A., D.Litt., F.R.S.E. 49A Grove-street, Liverpool.
1865. *Lloyd, Wilson, F.R.G.S. Park Lane House, Wednesbury.
1854. *LOBLEY, J. LOGAN, F.G.S., F.R.G.S. 36 Palace-street, Buckingham Gate, S.W.
1892. †LOCH, C. S., B.A. Denison House, Vauxhall Bridge-road, S.W.
1905. †Lochrane, Miss T. 8 Prince's-gardens, Dowanhill, Glasgow.
1904. †Lock, Rev. J. B. Herschel House, Cambridge.
1863. †LOCKYER, Sir J. NORMAN, K.C.B., LL.D., F.R.S. (PRESIDENT, 1903; Council, 1871-76, 1901-02.) 16 Penywern-road, S.W.
1902. *Lockyer, Lady. 16 Penywern-road, S.W.
1900. §LOCKYER, W. J. S., Ph.D. 16 Penywern-road, S.W.
1886. *LODGE, ALFRED, M.A. The Croft, Peperharow-road, Godalming.

Year of
Election.

1875. ***LODGE**, Sir **OLIVER J.**, D.Sc., LL.D., F.R.S. (VICE-PRESIDENT, 1907; Pres. A, 1891; Council, 1891-97, 1899-1903), Principal of the University of Birmingham.
1894. ***Lodge**, Oliver W. F. 17 Ruskin-buildings, Westminster, S.W.
1896. §**LOMAS**, J., F.G.S. 13 Moss-grove, Birkenhead.
1899. §**Loncq**, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1902. †**LONDONDERRY**, The Marquess of, K.G. Londonderry House, Park-lane, W.
1903. †**Long**, Frederick. The Close, Norwich.
1905. §**Long**, W. F. City Engineer's Office, Cape Town.
1883. ***Long**, William. Thelwall Heys, near Warrington.
1904. ***Longden**, J. A., M.Inst.C.E. Stanton-by-Dale, Nottingham.
1905. §**Longden**, Mrs. J. B. Stanton-by-Dale, Nottingham.
1898. ***Longfield**, Miss Gertrude. Belmont, High Halstow, Rochester.
1901. ***Longstaff**, Frederick V., F.R.G.S. Ridgelsands, Wimbledon, Surrey.
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. Ridgelsands, Wimbledon, S.W.
1881. ***Longstaff**, Mrs. Ll. W. Ridgelsands, Wimbledon, S.W.
1899. ***Longstaff**, Tom G., B.A., F.R.Met.Soc. Ridgelsands, Wimbledon, S.W.
1883. ***Longton**, E. J., M.D. Brown House, Blawith, viâ Ulverston.
1903. †**Loton**, John, M.A. 23 Hawkshead-street, Southport.
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, M.A., Professor of Mining in the Durham College of Science, Newcastle-on-Tyne.
1887. ***LOVE**, A. E. H., M.A., D.Sc., F.R.S., Professor of Natural Philosophy in the University of Oxford. 34 St. Margaret's-road, Oxford.
1886. ***Love**, E. F. J., M.A. The University, Melbourne, Australia.
1904. ***Love**, J. B. Outlands, Devonport.
1876. ***Love**, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1905. †**Loveday**, Professor T. South African College, Cape Town.
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.
1905. †**Lowe**, E. C. Chamber of Trade, Johannesburg.
1886. ***Lowe**, John Landor, B.Sc., M.Inst.C.E. Spondon, Derbyshire.
1894. †**Lowenthal**, Miss Nellie. Woodside, Egerton, Huddersfield.
1903. ***LOWRY**, Dr. T. MARTIN. 130 Horseferry-road, S.W.
1901. ***Lucas**, Keith. Greenhall, Forest Row, Sussex.
1891. ***Lucovich**, Count A. Tyn-y-parc, Whitchurch, near Cardiff
1906. §**Ludlam**, Ernest Bowman. Ackworth School, Pontefract, Yorks.
1866. ***Lund**, Charles. Ilkley, Yorkshire.
1850. ***Lundie**, Cornelius. 32 Newport-road, Cardiff.
1905. †**Lunnon**, F. J. P.O. Box 400, Pretoria.
1883. ***Lupton**, Arnold, M.Inst.C.E., F.G.S. 6 De Grey-road, Leeds.
1874. ***LUPTON**, SYDNEY, M.A. (Local Sec. 1890.) 102 Park-street, Grosvenor-square, W.
1864. ***Lutley**, John. Brockhampton Park, Worcester.
1898. §**Luxmoore**, Dr. C. M. University College, Reading.
1903. §**Lyddon**, Ernest H. Lisvane, near Cardiff.
1884. †**Lyman**, H. H. 384 St. Paul-street, Montreal, Canada.
1862. ***LYTE**, F. MAXWELL, M.A., F.C.S. 17 Mentone-mansions, Fulham-road, S.W.

Year of
Election.

1905. †Maberly, Dr. John. Shirley House, Woodstock, Cape Colony.
1868. †MACALISTER, ALEXANDER, M.A., M.D., F.R.S. (Pres. H, 1892 ; Council, 1901-06), Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. †MACALISTER, DONALD, M.A., M.D., LL.D., B.Sc. St. John's College, Cambridge.
1904. †Macalister, Miss M. A. M. Torrisdale, Cambridge.
1896. †MACALLUM, Professor A. B., Ph.D., F.R.S. (Local Sec. 1897.) 59 St. George-street, Toronto, Canada.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. †MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1866. *M'Arthur, Alexander. 79 Holland-park, W.
1896. *Macaulay, F. S., M.A. 19 Dewhurst-road, W.
1904. *Macaulay, W. H. King's College, Cambridge.
1896. †MACBRIDE, Professor E. W., M.A., F.R.S. McGill University, Montreal, Canada.
1902. *Maccall, W. T., M.Sc. 223 Burrage-road, Plumstead.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1887. *McCarthy, James. Care of Sir Sherston Baker, Bart., 18 Cavendish-road, Regent's Park, N.W.
1904. §McClellan, Frank Kennedy. Rusthall House, Tunbridge Wells.
1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1902. †McClelland, J. A., M.A., Professor of Physics in University College, Dublin.
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.
1906. §McClure, Rev. E. 80 Eccleston-square, S.W.
1878. *M'Comas, Henry. Pembroke House, Pembroke-road, Dublin.
1901. *MacConkey, Alfred. Queensberry Lodge, Elstree, Herts.
1905. †McConnell, D. E. Montrose-avenue, Orangezicht, Cape Town.
1901. †MacCormac, J. M., M.D. 31 Victoria-place, Belfast.
1892. *McCowan, John, M.A., D.Sc. Henderson-street, Bridge of Allan, N.B.
1901. †McCrae, John, Ph.D. 7 Kirklee-gardens, Glasgow.
1905. §McCulloch, Principal J. D. Free College, Edinburgh.
1904. †McCulloch, Major T., R.A. 68 Victoria-street, S.W.
1904. †Macdonald, H. M., M.A., F.R.S., Professor of Mathematics in the University of Aberdeen.
1905. §McDonald, J. G. P.O. Box 67, Bulawayo.
1900. †MacDonald, J.R., M.P. 3 Lincoln's Inn-fields, W.C.
1890. *MacDonald, Mrs. J. R. 3 Lincoln's Inn-fields, W.C.
1905. §Macdonald, J. S., B.A., Professor of Physiology in the University of Sheffield.
1884. *Macdonald, Sir W. C. 449 Sherbrooke-street West, Montreal, Canada.
1897. †McEwen, William C. 9 South Charlotte-street, Edinburgh.
1902. †Macfadyen, Allan, M.D., B.Sc. Lister Institute of Preventive Medicine, Chelsea-gardens, S.W.
1906. §McFarlane, John. 30 Parsonage-road, Withington, Manchester.
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.
1905. †Macfarlane, T. J. M. P.O. Box 1198, Johannesburg.
1901. †Macfee, John. 5 Greenlaw-terrace, Paisley.
1888. †MacGeorge, James. 7 Stonor-road, Kensington, W.
1906. §Macgregor, D. H., M.A. Trinity College, Cambridge.
1884. *MACGREGOR, JAMES GORDON, M.A., D.Sc., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh.

Year of
Election.

1902. †McIlroy, Archibald. Glenvale, Drumbo, Lisburn, Ireland.
1905. †Macindoe, Flowerdue. 23 Saratoga-avenue, Johannesburg.
1867. *McINTOSH W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S. (Pres. D. 1885), Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1884. §MacKay, A H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1885. †MACKAY, JOHN YULE, M.D., LL.D., Principal of and Professor of Anatomy in University College, Dundee.
1896. *McKechnie, Duncan. Eccleston Grange, Prescot.
1873. †McKENDRICK, JOHN G., M.D., LL.D., F.R.S., F.R.S.E. (Pres. I, 1901; Council, 1903-), Professor of Physiology in the University of Glasgow. 2 Buckingham-terrace, Glasgow.
1905. †McKenzie, A. R. P.O. Box 214, Cape Town.
1905. §Mackenzie, Hector. Standard Bank of South Africa, Cape Town.
1905. †Mackenzie, J. 13 Derwent-road, Kloof-road, Cape Town.
1897. †McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1901. *Mackenzie, Thomas Brown. Elenslee, Motherwell, N.B.
1872. *Mackey, J. A. United University Club, Pall Mall East, S.W.
1901. †Mackie, William, M.D. 13 North-street, Elgin.
1887. †MACKINDER, H. J., M.A., F.R.G.S. (Pres. E, 1895; Council, 1904-1905.) London School of Economics, Clare Market, W.C.
1885. *McLAREN, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1894. *McLaren, Mrs. E. L. Colby, M.B., Ch.B. 11 Leopold-place, Edinburgh.
1905. §McLaren, Thomas. P.O. Box 1034, Johannesburg.
1901. †Maclay, William. Thornwood, Langside, Glasgow.
1901. †McLean, Angus, B.Sc. Ascog, Meikleriggs, Paisley.
1905. §MacLean, Lachlan. Greenhill, Kenilworth, Cape Colony.
1892. *MACLEAN, MAGNUS, M.A., D.Sc., F.R.S.E. (Local Sec. 1901), Professor of Electrical Engineering, Technical College, Glasgow.
1905. *Maclear, Admiral J. P. Beaconsroft, Chiddingfold, Godalming.
1868. §McLEOD, HERBERT, F.R.S. (Pres. B, 1892; Council, 1885-90.) 9 Coverdale, Richmond, Surrey.
1883. †MACMAHON, Major PERCY A., R.A., D.Sc., F.R.S. (GENERAL SECRETARY, 1902- ; Pres. A, 1901; Council, 1898-1902.) Queen Anne's-mansions, Westminster, S.W.
1902. †McMordie, Robert J. Cabin Hill, Knock, Co. Down.
1905. †MacNay, Arthur. Cape Government Railway Offices, De Aar, Cape Colony.
1878. †Macnie, George. 59 Bolton-street, Dublin.
1905. §Macphail, Dr. S. Rutherford. Rowditch, Derby.
1905. †Macrae, Harold J. P.O. Box 817, Johannesburg.
1906. §Macturk, G. W. B. 15 Bowlalley-lane, Hull.
1902. †McWeeney, E. J., M.D. 84 Stephen's-green, Dublin.
1902. †McWhirter, William. 9 Walworth-terrace, Glasgow.
1905. §Magenis, Lady Louisa. 34 Lennox-gardens, S.W.
1902. †Magill, R., M.A., Ph.D. The Manse, Maghera, Co. Derry.
1875. *MAGNUS, Sir PHILIP, B.Sc., M.P. 16 Gloucester-terrace, Hyde-park, W.
1902. †Mahon, J. L. 2 May-street, Drumcondra, Dublin.
1857. †MALLEY, 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.
1905. §Maltby, Lieutenant G. R., R.N. 54 St. George's-square, S.W.

Year of
Election.

1897. †MANCE, Sir H. C. 32 Earl's Court-square, S.W.
 1903. †Manifold, C. C. 16 St. James's-square, S.W.
 1905. †Manning, D. W., F.R.G.S. Roydon, Rosebank, Cape Town.
 1894. †Manning, Percy, M.A., F.S.A. Watford, Herts.
 1905. †Mansfield, J. D. 94 St. George's-street, Cape Town.
 1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester,
 Dorsetshire.
 1902. *Marchant, Dr. E. W. The University, Liverpool.
 1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
 1900. †Margerison, Samuel. Calverley Lodge, near Leeds.
 1864. †MARKHAM, Sir CLEMENTS R., K.C.B., F.R.S., F.R.G.S., F.S.A.
 (Pres. E, 1879; Council, 1893-96.) 21 Eccleston-square, S.W.
 1905. §Marks, Samuel. P.O. Box 379, Pretoria.
 1905. †Marloth, R., M.A., Ph.D. P.O. Box 359, Cape Town.
 1881. *MARR, J. E., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1896; Council,
 1896-1902.) St. John's College, Cambridge.
 1903. §Marriott, William. Royal Meteorological Society, 70 Victoria-
 street, S.W.
 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 Carpenter. 3 Lower James-street, Golden-square, W.
 1887. †Marsh, J. E., M.A., F.R.S. University Museum, Oxford.
 1889. *MARSHALL, ALFRED, M.A., LL.D., D.Sc. (Pres. F, 1890), Professor
 of Political Economy in the University of Cambridge. Balliol
 Croft, Madingley-road, Cambridge.
 1904. †Marshall, F. H. A. University of Edinburgh.
 1905. §Marshall, G. A. P.O. Box 149, Salisbury, Cape Colony.
 1892. §Marshall, Hugh, D.Sc., F.R.S., F.R.S.E. 12 Lonsdale-terrace,
 Edinburgh.
 1901. †Marshall, Robert. 97 Wellington-street, Glasgow.
 1886. *MARSHALL, WILLIAM BAYLEY, M.Inst.C.E. 21 St. John's Wood-
 park, N.W.
 1899. §Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.
 1891. *Martin, Edward P., J.P. The Hill, Abergavenny, Monmouth-
 shire.
 1905. †Martin, John. P.O. Box 217, Germiston, Transvaal.
 1884. §Martin, N. H., J.P., F.R.S.E., F.L.S. Ravenswood, Low Fell,
 Gateshead.
 1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Northdene, New
 Barnet, Herts.
 1883. †MARWICK, Sir J. D., LL.D., F.R.S.E. (Local Sec. 1871, 1876, 1901.)
 Glasgow.
 1905. †Marwick, J. S. P.O. Box 1166, Johannesburg.
 1905. †Marx, Mrs. Charles. Shabana, Robinson-street, Belgravia, South
 Africa.
 1847. †MASKELYNE, NEVIL STORY, M.A., D.Sc., F.R.S., F.G.S. (Council,
 1874-80). Basset Down House, Swindon.
 1905. *Mason, Justice A. W. Supreme Court, Pretoria.
 1893. *Mason, Thomas. Enderleigh, Alexandra-park, Nottingham.
 1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
 1905. §Massy, Miss Mary. York House, Teignmouth, Devon.
 1898. †Masterman, A. T. University of St. Andrews, N.B.
 1901. *Mather, G. R. Boxlea, Wellingborough.
 1887. *Mather, Sir William, M.Inst.C.E. Salford Iron Works, Man-
 chester.
 1905. †Mathew, Alfred Harfield. P.O. Box 242, Cape Town.

Year of
Election.

1894. †MATHEWS, G. B., M.A., F.R.S. St. John's College, Cambridge.
 1902. †Matley, C. A., D.Sc. 7 Morningside-terrace, Edinburgh.
 1904. †Matthews, D. J. The Laboratory, Citadel Hill, Plymouth.
 1905. †Matthews, J. Wright, M.D. P.O. Box 437, Johannesburg.
 1893. †Mavor, Professor James. University of Toronto, Canada.
 1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall, Kenley, Surrey.
 1894. §Maxim, Sir Hiram S. Thurlow Park, Norwood-road, West
 Norwood, S.E.
 1903. †Maxwell, J. M. 37 Ash-street, Southport.
 1901. *May, W. Page, M.D., B.Sc. 9 Manchester-square, W.
 1884. *Maybury, A. C., D.Sc. 8 Heathcote-street, W.C.
 1905. §Maylard, A. Ernest. 10 Blythswood-square, Glasgow.
 1905. †Maylard, Mrs. 10 Blythswood-square, Glasgow.
 1878. *Mayne, Thomas. 33 Castle-street, Dublin.
 1904. †Mayo, Rev. J., LL.D. 6 Warkworth-terrace, Cambridge.
 1905. †Mearns, J. Herbert, M.D. Edenville, 10 Oxford-road, Observatory,
 Cape Town.
 1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
 1905. †Mein, W. W. P.O. Box 1024, Johannesburg.
 1881. *MELDOLA, RAPHAEL, F.R.S., F.R.A.S., F.C.S., F.I.C. (Pres. B,
 1895; Council, 1892-99), Professor of Chemistry in the Fins-
 bury Technical College, City and Guilds of London Institute.
 6 Brunswick-square, W.C.
 1883. †Mellis, Rev. James. 23 Part-street, Southport.
 1879. *Mellish, Henry. Hodsock Priory, Worksop.
 1866. †MELLO, Rev. J. M., M.A., F.G.S. Cliff Hill, Warwick.
 1896. §Mellor, G. H. Weston, Blundellsands, Liverpool.
 1881. §Melrose, James. Clifton Croft, York.
 1905. *Melvill, E. H. V., F.G.S., F.R.G.S. P.O. Box 719, Johannesburg.
 1901. †Mennell, F. P. 8 Addison-road, W.
 1862. †MENNELL, HENRY T. St. Dunstan's-buildings, Great Tower-
 street, E.C.
 1905. §Meredith, H. O. Dunwood House, Withington, Manchester.
 1879. †MERIVALE, JOHN HERMAN, M.A. (Local Sec. 1889.) Togston Hall,
 Acklington.
 1899. *Merrett, William H., F.I.C. Hatherley, Grosvenor-road, Walling-
 ton, Surrey.
 1905. †Merriman, Hon. John X. Schoongezicht, Stellenbosch, Cape
 Colony.
 1899. †Merryweather, J. C. 4 Whitehall-court, S.W.
 1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
 1905. †Methven, Cathcart W. Club Arcade, Smith-street, Durban.
 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. (Pres. D, 1897; Local
 Sec. 1890), Professor of Biology in the University of Leeds.
 Richmond-mount, Headingley, Leeds.
 1903. †Micklethwait, Miss F. G. Queen's College, Galway.
 1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of.
 Bishop's House, Middlesbrough.
 1904. †Middleton, T. H., M.A., Professor of Agriculture in the University
 of Cambridge. South House, Barton-road, Cambridge.
 1894. *MIERS, H. A., M.A., F.R.S., F.G.S. (Pres. C, 1905), Professor of
 Mineralogy in the University of Oxford. Magdalen College,
 Oxford.
 1885. §MILL, HUGH ROBERT, D.Sc., LL.D., F.R.S.E., F.R.G.S. (Pres. E,
 1901.) 62 Camden-square, N.W.

- Year of Election.
1905. §Mill, Mrs. H. R. 62 Camden-square, N.W.
1889. *MILLAR, ROBERT COCKBURN, 30 York place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1895. †Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1902. †Millin, S. T. Sheridan Lodge, Helen's Bay, Co. Down.
1904. †Millis, C. T. Hollydene, Wimbledon Park-road, Wimbledon.
1905. §Mills, Mrs. A. A. 36 St. Andrews-street, Cambridge.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S. 64 Twyford-avenue,
West Acton, W.
1902. †Mills, W. Sloan, M.A. Vine Cottage, Donaghmore, Newry.
1882. *MILNE, JOHN, D.Sc., F.R.S., F.G.S. Shide, Newport, Isle of
Wight.
1903. *Milne, R. M. Royal Naval College, Dartmouth, South Devon.
1898. *Milner, S. Roslington, D.Sc. The University, Sheffield.
1880. †MINCHIN, G. M., M.A., F.R.S., Professor of Mathematics in the
Royal Indian Engineering College, Coopers Hill, Surrey.
1901. *Mitchell, Andrew Acworth. 7 Huntly-gardens, Glasgow.
1901. *Mitchell, G. A. 5 West Regent-street, Glasgow.
1905. †Mitchell, John. Government School House, Jeppestown, Trans-
vaal.
1885. †MITCHELL, P. CHALMERS, M.A., D.Sc., F.R.S., Sec.Z.S. (Council,
1906-) 3 Hanover-square, W.
1905. *Mitchell, William Edward. Ferreira Deep, Johannesburg.
1905. †Mitter, M. Care of J. Speak, Esq., The Grange, Kirton, near
Boston.
1895. *Moat, William, M.A. Johnson Hall, Eccleshall, Staffordshire.
1905. §Moir, James, D.Sc. Mines Department, Johannesburg.
1905. †Moir, Dr. W. Ironside. Care of Dr. McAulay, Cleveland, Trans-
vaal.
1905. §Molengraaff, Professor G. A. F. The Technical University of
Delft, The Hague.
1883. †Mollison, W. L., M.A. Clare College, Cambridge.
1900. *MONCKTON, H. W., Treas.L.S., F.G.S. 3 Harcourt-buildings,
Temple, E.C.
1905. *MONCRIEFF, Colonel Sir C. SCOTT, G.C.S.I., K.C.M.G., R.E. (Pres.
G, 1905.) 11 Cheyne-walk, S.W.
1905. †Moncrieff, Lady Scott. 11 Cheyne-walk, S.W.
1887. *MOND, LUDWIG, Ph.D., D.Sc., F.R.S., F.C.S. (Pres. B, 1896.)
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. 12 Kensington Palace-gardens, W.
1905. *Moore, Brian. Thornhill Villa, Marsh, Huddersfield.
1905. †Moore, Charles Elliott. P.O. Box 5382, Johannesburg.
1894. §Moore, Harold E. Oaklands, The Avenue, Beckenham, Kent.
1901. *Moore, Robert T. 142 St. Vincent-street, Glasgow.
1905. §Moore, T. H. Thornhill Villa, Marsh, Huddersfield.
1896. *Mordey, W. M. 82 Victoria-street, S.W.
1905. †More, T. E. Padern. Cariton Buildings, Parliament-street, Cape
Town.
1901. *Moreno, Francisco P. La Plata Museum, Argentina.
1905. *Morgan, Miss Annie. Friedrichstrasse No. 2, Vienna.
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.
1896. †Morgan, George. 21 Upper Parliament-street, Liverpool.

Year of
Election.

1902. †MORGAN, GILBERT T., D.Sc., F.I.C. Royal College of Science, S.W.
 1902. *Morgan, Septimus Vaughan. 37 Harrington-gardens, S.W.
 1901. *Morison, James. Perth.
 1883. *MORLEY, HENRY FORSTER, M.A., D.Sc., F.C.S. 5 Lyndhurst-road,
 Hampstead, N.W.
 1906. §Morrell, H. R. Scarcroft-road, York.
 1896. †Morrell, R. S. Caius College, Cambridge.
 1905. †Morris, F., M.B., B.Sc. 18 Hope-street, Cape Town.
 1896. *Morris, J. T. 13 Somers-place, W.
 1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
 1899. §MORROW, JOHN, M.Sc., D.Eng. Armstrong College, Newcastle-
 upon-Tyne.
 1865. †Mortimer, J. R. St. John's Villas, Driffield.
 1886. *Morton, P. F. 15 Ashley-place, Westminster, S.W.
 1896. *MORTON, WILLIAM B., M.A., Professor of Natural Philosophy in
 Queen's College, Belfast.
 1878. *MOSS, JOHN FRANCIS, F.R.G.S. (Local Sec. 1879.) Edgebrook
 Cottage, Brincliffe, Sheffield.
 1876. §MOSS, RICHARD JACKSON, F.I.C., M.R.I.A. Royal Dublin Society,
 and St. Aubyn's, Ballybrack, Co. Dublin.
 1892. *Mostyn, S. G., M.A., M.B. Health Office, South Shields.
 1866. †MOTT, FREDERICK T., F.R.G.S. Crescent House, Leicester.
 1878. *MOULTON, The Right Hon. Lord Justice, M.A., K.C., F.R.S.
 57 Onslow-square, S.W.
 1899. §Mowll, Martyn. Chaldercot, Leyburne-road, Dover.
 1905. §Moylan, Miss V. C. 3 Canning-place, Palace Gate, W.
 1905. *Moysey, Miss E. L. Pitcroft, Guildford, Surrey.
 1899. *Muff, Herbert B. Geological Survey Office, 33 George-square,
 Edinburgh.
 1902. §Muir, Arthur H., C.A. 2 Wellington-place, Belfast.
 1874. †MUIR, M. M. PATTISON, M.A. Gonville and Caius College, Cam-
 bridge.
 1904. §Muir, William. Rowallan, Newton Stewart, N.B.
 1872. *MUIRHEAD, ALEXANDER, D.Sc., F.R.S., F.C.S. 12 Carteret-street,
 Queen Anne's Gate, Westminster, S.W.
 1905. *Muirhead, James M. P. Markham's-chambers, St. George's-street,
 Cape Town.
 1876. *Muirhead, Robert Franklin, M.A., D.Sc. 24 Kersland-street,
 Hillhead, Glasgow.
 1902. †Mullan, James. Castlerock, Co. Derry.
 1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East,
 Regent's Park, N.W.
 1905. †Mulligan, A. 'Natal Mercury' Office, Durban, Natal.
 1904. §Mullinger, J. Bass, M.A. St. John's College, Cambridge.
 1898. †Mumford, C. E. Cross Roads House, Bouverie-road, Folkestone.
 1901. *Munby, Alan E. Royal Societies Club, St. James's-street, S.W.
 Munby, Arthur Joseph. 6 Fig Tree-court, Temple, E.C.
 1906. §Munby, Frederick J. Whixley, York.
 1904. †Munro, A. Queens' College, Cambridge.
 1883. *MUNRO, ROBERT, M.A., M.D., LL.D. (Pres. H, 1893.) Elmbank,
 Largs, Ayrshire, N.B.
 1890. †Murphy, A. J. Springfield Mount, Leeds.
 1884. §Murphy, Patrick. Marcus-square, Newry, Ireland.
 1905. §Murray, Charles F. K., M.D. Kenilworth House, Kenilworth,
 Cape Colony.
 1905. †Murray, Dr. F. Londinium, London-road, Sea Point, Cape
 Town.

Year of
Election.

1891. †MURRAY, G. R. M., F.R.S., F.R.S.E., F.L.S. 8 Kerrison-road, Ealing, W.
1905. §Murray, Dr. J. A. H. Sunnyside, Oxford.
1905. §Murray, Mrs. Sunnyside, Oxford.
1884. †MURRAY, Sir JOHN, K.C.B., LL.D., D.Sc., Ph.D., F.R.S., F.R.S.E. (Pres. E, 1899.) House of Falkland, Falkland, N.B.
1903. †Murray, J.D. Rowbottom-square, Wigan.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1902. †Myddleton, Alfred. 62 Duncairn-street, Belfast.
1902. *Myers, Charles S., M.A., M.D. Melrose, Grange-road, Cambridge.
1906. §Myers, Jesse A. Glengarth, Walker-road, Harrogate.
1890. *MYRES, JOHN L., M.A., F.S.A. 1 Norham-gardens, Oxford.
1886. †NAGEL, D. H., M.A. (Local Sec. 1894.) Trinity College, Oxford.
1892. *Nairn, Sir Michael B., Bart. Kirkcaldy, N.B.
1890. †Nalder, Francis Henry. 34 Queen-street, E.C.
1905. †Napier, Dr. Francis. 73 Jeppe-street, Von Brandis-square, Johannesburg.
1872. †NARES, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 11 Claremont-road, Surbiton.
1883. *Neild, Theodore, B.A. The Vista, Leominster.
1898. *Nevill, Rev. J. H. N., M.A. 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.
1889. *Newall, H. Frank, M.A., F.R.S., F.R.A.S. Madingley Rise, Cambridge.
1901. †Newman, F. H. Tullie House, Carlisle.
1889. †Newstead, A. H. L., B.A. 38 Green-street, Bethnal Green, N.E.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S. (Pres. D, 1887 ; Council, 1875-82), 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.
1887. *Nicholson, John Carr, J.P. Moorfield House, Headingley, Leeds.
1884. †NICHOLSON, JOSEPH S., M.A., D.Sc. (Pres. F, 1893), Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1863. *NOBLE, Sir ANDREW, Bart., K.C.B., D.Sc., F.R.S., F.R.A.S., F.C.S. (Pres. G, 1890 ; Council, 1903-06 ; Local Sec. 1863.) ; Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.
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.
1883. *Norris, William G. Dale House, Coalbrookdale, R.S.O., Shropshire.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. (Local Sec. 1895.) Constitution-hill, Ipswich.
1903. †Noton, John. 45 Part-street, Southport.
1898. *O'Brien, Neville Forth. Queen Anne's-mansions, S.W.
1883. †Ogders, William Blake, M.A., LL.D., K.C. 15 Old-square, Lincoln's Inn, W.C.

Year of
Election.

1858. *ODLING, WILLIAM, M.B., F.R.S., V.P.C.S. (Pres. B, 1864 ; Council, 1865-70), Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1894. †Ogden, James. Kilner Deyne, Rochdale.
1902. §Ogden, James Neal. Claremont, Heaton Chapel, Stockport.
1876. †Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. †OGILVIE, F. GRANT, C.B., M.A., B.Sc., F.R.S.E. (Local Sec. 1892.) Board of Education, S.W.
1905. *Oke, Alfred William, B.A., LL.M., F.G.S., F.L.S. 32 Denmark-villas, Hove, Brighton.
1905. §Okell, Samuel. Overley, Langham-road, Bowdon, Cheshire.
1892. †OLDHAM, H. YULE, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1893. *OLDHAM, R. D., F.G.S., Geological Survey of India. Care of Messrs. H. S. King & Co., 9 Pall Mall, S.W.
1863. †OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. †OLIVER, F. W., D.Sc., F.R.S., F.L.S. (Pres. K, 1906), Professor of Botany in University College, London. 2 The Vale, 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.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1902. †O'Neill, Henry, M.D. 6 College-square, East Belfast.
1902. †O'Neill, James, M.A. 5 College-square, East Belfast.
1902. †O'Reilly, Patrick Joseph. 7 North Earl-street, Dublin.
1905. †O'Riley, J. C. 70 Barnet-street, Gardens, Cape Town.
1883. †Orpen, Miss. St Leonard's, Killiney, Co. Dublin.
1884. *Orpen, Lieut.-Colonel R. T., R.E., St Leonard's, Killiney, Co. Dublin.
1884. *Orpen, Rev. T. H., M.A. The Vicarage, Great Shelford, Cambridge.
1901. §Orr, Alexander Stewart. Care of Messrs. Marsland, Price, & Co., Nesbit-road, Mazagon, Bombay, India.
1905. †Orr, Professor John. Transvaal Technical Institute, Johannesburg.
1904. *Orton, K. J. P., M.A., Ph.D., Professor of Chemistry in University College, Bangor.
1905. †Osborn, Philip B. P.O. Box. 4181, Johannesburg.
1901. †Osborne, W. A., D.Sc. University College, W.C.
1887. †O'Shea, L. T., B.Sc. University College, Sheffield.
1865. *Osler, Henry F. Copsy-hill, Linthurst, near Bromsgrove, Birmingham.
1884. †OSLER, WILLIAM, M.D., LL.D., F.R.S., Regius Professor of Medicine in the University of Oxford. University Museum, Oxford.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1896. †Oulton, W. Hillside, Gateacre, Liverpool.
1906. §Owen, Rev. E. C. St. Peter's School, York.
1903. *Owen, Edwin, M.A. Terra Nova School, Birkdale, Lancashire.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1896. §Owen, Peter. The Elms, Capenhurst, Chester.
1906. §Page, Carl D. Wyoming House, Aylesbury, Bucks.
1903. *Page, Miss Ellen Iva. Turret House, Felpham, Sussex.

Year of
Election.

1870. *PALGRAVE, ROBERT HARRY INGLIS, F.R.S., F.S.S. (Pres. F, 1883.)
Belton, Great Yarmouth.
1878. *Palmer, Joseph Edward. Rose Lawn, Ballybrack, Co. Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1905. §Palmer, William. Durban, Natal.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield,
Yorkshire.
1904. †PARKER, E. H., M.A. Thorneycreek, Herschel-road, Cambridge.
1905. †Parker, Hugh. P.O. Box 200, Pietermaritzburg, Natal.
1905. †Parker, John. 37 Hout-street, Cape Town.
1905. *Parker, Thomas Edward. P.O. Box 4580, Johannesburg.
1891. †PARKER, WILLIAM NEWTON, Ph.D., F.Z.S., Professor of Biology in
University College, Cardiff.
1899. *Parkin, John. Blaithwaite, Carlisle.
1905. *Parkin, Thomas. Blaithwaite, Carlisle.
1906. §Parkin, Thomas, M.A., F.Z.S., F.R.G.S. Fairseat, High Wick-
ham, Hastings.
1879. *Parkin, William. The Mount, Sheffield.
1903. §Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo, near Liverpool.
1878. †PARSONS, Hon. C. A., C.B., M.A., Sc.D., F.R.S., M.Inst.C.E.
(Pres. G, 1904.) Holeyn Hall, Wylam-on-Tyne.
1904. †Parsons, Professor F. G. St. Thomas's Hospital, S.E.
1905. *Parsons, Hon. Geoffrey L. Northern Counties Club, Newcastle-on-
Tyne.
1898. *Partridge, Miss Josephine M. 15 Grosvenor-crescent, S.W.
1887. †PATERSON, A. M., M.D., Professor of Anatomy in the University
of Liverpool.
1897. †Paton, D. Noël, M.D. Physiological Laboratory, The University,
Glasgow.
1883. *Paton, Rev. Henry, M.A. 120 Polwarth-terrace, Edinburgh.
1884. *Paton, Hugh. Box 2400, Montreal, Canada.
1902. †Patterson, Robert, F.Z.S., M.R.I.A. *Ivy Dene, Malone-park,*
Belfast.
1874. †Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1879. *Patzner, F. R. Clayton Lodge, Newcastle, Staffordshire.
1883. †Paul, George. 32 Harlow Moor-drive, Harrogate.
1863. †PAVY, FREDERICK WILLIAM, M.D., LL.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.
1877. *Payne, J. C. Charles, J.P. Albion-place, The Plains, Belfast.
1881. †Payne, Mrs. Albion-place, The Plains, Belfast.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1876. †Peace, G. H., M.Inst.C.E. Monton Grange, Eccles, near Man-
chester.
1906. §Peace, Miss Gertrude. 39 Westbourne-road, Sheffield.
1885. †PEACH, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office,
Edinburgh.
1886. *Pearce, Mrs. Horace. Collingwood, Manby-road, West Malvern.
1905. †Pearse, S. P.O. Box 149, Johannesburg.
1883. †Pearson, Arthur A. Colonial Office, S.W.
1893. *Pearson, Charles E. Hillcrest, Lowdham, Nottinghamshire.
1898. §Pearson, George. Bank-chambers, Baldwin-street, Bristol.
1905. §Pearson, Professor H. H. W., M.A., F.L.S. South African College,
Cape Town.
1883. †Pearson, Miss Helen E. Oakhurst, Birkdale, Southport,

Year of
Election.

1906. §Pearson, Joseph. The University, Liverpool.
1904. †Pearson, Karl, M.A., F.R.S., Professor of Applied Mathematics in University College, London, W.C.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *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.
1884. †Peebles, W. E. 9 North Frederick-street, Dublin.
1878. *Peek, William. Dorman's Park, near East Grinstead.
1901. *Peel, Hon. William. 13 King's Bench-walk, Temple, E.C.
1905. §Peirson, J. Waldie. P.O. Box 561, Johannesburg.
1905. §Pemberton, Gustavus M. P.O. Box 93, Johannesburg.
1887. †PENDLEBURY, WILLIAM H., M.A., F.C.S. (Local Sec. 1899.) Woodford House, Mountfields, Shrewsbury.
1894. †Pengelly, Miss. Lamorna, Torquay.
1896. †Pennant, P. P. Nantlys, St. Asaph.
1898. †Pentecost, Rev. Harold, M.A. The School, Giggleswick, Yorkshire.
1898. †Percival, Francis W., M.A., F.R.G.S. 1 Chesham-street, S.W.
1905. †Péringuey, L., F.Z.S. South African Museum, Cape Town.
1894. †PERKIN, A. G., F.R.S., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Hyde Park, Leeds.
1902. †Perkin, F. Mollwo, Ph.D. The Firs, Hengrave-road, Honor Oak Park, S.E.
1868. *PERKIN, Sir WILLIAM HENRY, Ph.D., LL.D., D.Sc., F.R.S., F.C.S. (Pres. B, 1876; Council, 1880-86.) The Chestnuts, Sudbury, Harrow, Middlesex.
1884. †PERKIN, WILLIAM HENRY, jun., LL.D., Ph.D., F.R.S., F.R.S.E. (Pres. B, 1900; Council, 1901-), Professor of Organic Chemistry in the Victoria University, Manchester. Fairview, Wilbraham-road, Fallowfield, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P., D.Sc. University College, Cardiff.
1874. *PERRY, JOHN, M.E., D.Sc., LL.D., F.R.S. (GENERAL TREASURER, 1904- ; Pres. G, 1902; Council, 1901-04), Professor of Mechanics and Mathematics in the Royal College of Science, S.W.
1904. *Pertz, Miss D. F. M. 2 Cranmer-road, Cambridge.
1900. †Petavel, J. E. The Owens College, Manchester.
1901. †Pethybridge, G. H. Museum of Science and Art, Dublin.
1895. †PETRIE, W. M. FLINDERS, D.C.L., F.R.S. (Pres. H, 1895), Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth-avenue, Hove, Brighton.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, S.W.
1903. †Philip, James C. 20 Westfield-terrace, Aberdeen.
1905. †Philip, John W. P.O. Box 215, Johannesburg.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Elizabeth Lodge, Crescent-road, South Woodford, Essex.
1905. §Phillimore, Miss C. M. Shiplake House, Henley-on-Thames.
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.
1902. †Phillips, J. St. J., B.E. 64 Royal-avenue, Belfast.

Year of
Election.

1890. †Phillips, R. W., M.A., D.Sc., F.L.S., Professor of Botany in University College, Bangor. 2 Snowdon-villas, Bangor.
1905. §Phillip, Miss M. E. de R., B.Sc. 12 Crescent-grove, Clapham, S.W.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1901. §Pickard, Robert H., D.Sc. Isca, Merlin-road, Blackburn.
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.
1888. *Pidgeon, W. R. 42 Porchester-square, W.
1865. †PIKE, L. OWEN. 10 Chester-terrace, Regent's Park, N.W.
1896. *Pilkington, A. C. Rocklands, Rainhill, Lancashire.
1905. †Pilling, Arnold. Royal Observatory, Cape Town.
1896. *Pilling, William. Rosario, Heene-road, West Worthing.
1905. †Pim, Miss Gertrude. Charleville, Blackrock, Co. Dublin.
1893. *PITT, WALTER, M.Inst.C.E. South Stoke House, near Bath.
1900. *Platts, Walter. Fairmount, Bingley.
1898. §Plummer, W. E., M.A., F.R.A.S. The Observatory, Bidston, Birkenhead.
1900. *Pocklington, H. Cabourn. 41 Virginia-road, Leeds.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1904. §Pollard, William. 12 Aberdare-gardens, South Hampstead, N.W.
1896. *Pollex, Albert. Tenby House, Egerton Park, Rockferry.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1906. *Pontifex, Miss Catherine E. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1900. *POPE, W. J., F.R.S., Professor of Chemistry in the Municipal School of Technology, Manchester. Corchester, Bramhall, Cheshire.
1901. §Porter, Alfred W., B.Sc. 87 Parliament Hill-mansions, Lissenden-gardens, N.W.
1883. *Porter, Rev. C. T., LL.D., D.D. All Saints' Vicarage, Southport.
1905. §Porter, J. B., Ph.D., M.Inst.C.E., Professor of Mining Engineering in the McGill University, Montreal, Canada.
1905. †Porter, Mrs. McGill University, Montreal, Canada.
1883. †POTTER, M. C., M.A., F.L.S., Professor of Botany in the Armstrong College, Newcastle-upon-Tyne. 14 Highbury, Newcastle-upon-Tyne.
1906. §Potter-Kirby, Alderman George. Clifton Lawn, York.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S. (Pres. D, 1896; Council, 1895-1901, 1905-), Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1905. §Poulton, Mrs. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer, M.A. Wykeham House, Banbury-road, Oxford.
1905. §Poulton, Miss. Wykeham House, Banbury-road, Oxford.
1905. †Poulton, Miss M. 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, F.R.G.S. Wood Villa, Tettenhall Wood, Wolverhampton.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, Cavendish-square, W.
1887. §Pownall, George H. 20 Birchin-lane, E.C.
1883. †POYNTING, J. H., D.Sc., F.R.S. (Pres. A, 1899), Professor of Physics in the University of Birmingham. 10 Ampton-road, Edgbaston, Birmingham.

Year of
Election.

1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1906. §Pratt, Edwin M., D.Sc. The Woodlands, Silverdale, Lancashire.
1869. *PREECE, Sir WILLIAM HENRY, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1888 ; Council, 1888-95, 1896-1902.) Gothic Lodge, Wimbledon Common, S.W. ; and 8 Queen Anne's-gate, S.W.
1888. *Preece, W. Llewellyn. Bryn Helen, Woodborough-road, Putney, S.W.
1904. †Prentice, Mrs. Manning. Thelema, Undercliff-road, Felixstowe.
1892. §Prentice, Thomas. Willow Park, Greenock.
1906. §Pressly, D. L. Coney-street, York.
1889. §Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1893. *Preston, Martin Inett. 48 Ropewalk, Nottingham.
1905. †Pretoria, The Right Rev. the Bishop of, D.D. Pretoria.
1903. §Price, Edward E. Oaklands, Oaklands-road, Bromley, Kent.
Price, J. T. Neath Abbey, Glamorganshire.
1888. †PRICE, L. L. F. R., M.A., F.S.S. (Pres. F, 1895 ; Council, 1898-1904.) Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1897. *PRICE, W. A., M.A. 2 Vanbrugh-park, Blackheath, S.E.
1905. †Prince, James Perrott, M.D. Durban, Natal.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel-gardens, South Hampstead, N.W.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, W.
1881. §Procter, John William. Ashcroft, York.
Procter, William. Elmhurst, Higher Erith-road, Torquay.
1884. *Proudfoot, Alexander, M.D. 100 State-street, Chicago, U.S.A.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1871. *Puckle, Rev. T. J. Chestnut House, Huntingdon-road, Cambridge.
1867. *Pullar, Sir Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1903. §Pullen-Burry, Miss. Care of Mrs. Kilvington, Coniston, Avondale-road, South Croydon.
1904. †Punnett, R. C. Caius College, Cambridge.
1905. †Purcell, W. F., M.A., Ph.D. South African Museum, Cape Town.
1905. †Purcell, Mrs. W. F. South African Museum, Cape Town.
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.
1881. †Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1874. †PURSER, FREDERICK, M.A. Rathmines Castle, Dublin.
1866. †PURSER, Professor JOHN, M.A., LL.D., M.R.I.A. (Pres. A, 1902.) Rathmines Castle, Dublin.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1905. †Purvis, Mr. P.O. Box 744, Johannesburg.
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.

Year of
Election.

1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston, Southampton.
1887. *Ragdale, John Rowland. The Beeches, Stand, near Manchester.
1905. †Raine, Miss. P.O. Box 788, Johannesburg.
1905. †Raine, Robert. P.O. Box 1091, Johannesburg.
1898. *Raisin, Miss Catherine A., D.Sc., Bedford College, York-place, Baker-street, W.
1896. *RAMAGE, HUGH, M.A. The Technical Institute, Norwich.
1894. *RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1876. *RAMSAY, Sir WILLIAM, K.C.B., Ph.D., F.R.S. (Pres. B, 1897; Council, 1891-98), Professor of Chemistry in University College, London. 19 Chester-terrace, Regent's Park, N.W.
1883. †Ramsay, Lady. 19 Chester-terrace, Regent's Park, N.W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, W.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1861. †RANSOME, ARTHUR, M.A., M.D., F.R.S. (Local Sec. 1861.) Sunnyhurst, Deane Park, Bournemouth.
Ransome, Thomas. Hest Bank, near Lancaster.
1889. †Rapkin, J. B. Thrale Hall, Streatham, S.W.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, N.W.
1903. §Rastall, R. H. Christ's College, Cambridge.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1874. †RAVENSTEIN, E. G., F.R.G.S., F.S.S. (Pres. E, 1891.) 2 York-mansions, Battersea Park, S.W.
1905. †Rawson, Colonel Herbert E., R.E. Army Headquarters, Pretoria.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., Pres.R.S., F.R.A.S., F.R.G.S. (PRESIDENT, 1884; TRUSTEE, 1883-; Pres. A, 1882; Council, 1878-83), Professor of Natural Philosophy in the Royal Institution, London. Terling Place, Witham, Essex.
1895. †Raynbird, Hugh, jun. Garrison Gateway Cottage, Old Basing, Basingstoke.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree, M.A. 19 Tiviot Dale, Stockport.
1896. *READ, CHARLES H., F.S.A. (Pres. H, 1899.) British Museum, W.C.
1902. †Reade, R. H. Wilmount, Dunmurry.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1852. *REDFERN, Professor PETER, M.D. (Pres. D, 1874.) 4 Lower-crescent, Belfast.
1890. *Redwood, Sir Boverton, F.R.S.E., F.C.S. Wadham Lodge, Wadham-gardens, N.W.
1905. §Reed, J. Howard. Coal Exchange, Market-place, Manchester.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. Dunsear, Oaken, near Wolverhampton.
1891. *Rees, I. Treharne, M.Inst.C.E. Blaenypant, near Newport, Monmouthshire.
1903. §Reeves, E. A., F.R.G.S. 1 Savile-row, W.
1906. *Reichel, H. R., LL.D., Principal of University College, Bangor. Penrallt, Bangor, North Wales.
1901. *Reid, Andrew T. 10 Woodside-terrace, Glasgow.
1904. §Reid, Arthur H. P.O. Box 746, Johannesburg.
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.
1903. *Reid, Mrs. E. M., B.Sc. 7 St. James's-mansions, West End-lane, N.W.

Year of
Election.

1892. †REID, E. WAYMOUTH, B.A., M.B., F.R.S., Professor of Physiology in University College, Dundee.
1901. *Reid, Hugh. Belmont, Springburn, Glasgow.
1901. †Reid, John. 7 Park-terrace, Glasgow.
1904. †Reid, P. J. German Cottage, Marske-by-the-Sea.
1897. †Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1875. †REINOLD, A. W., M.A., F.R.S. (Council, 1890-95), Professor of Physics in the Royal Naval College, Greenwich, S.E.
1894. †Rendall, Rev. G. H., M.A., Litt.D. Charterhouse, Godalming.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1903. §RENDLE, Dr. A. B., M.A., F.L.S. 47 Wimbledon Park-road, Wimbledon.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1906. §Rennie, John, D.Sc. Natural History Department, University of Aberdeen.
1905. *Renton, James Hall. Rowfold Grange, Billingham, Sussex.
1905. †Reunert, Clive. Windybrow, Johannesburg.
1905. †Reunert, John. Windybrow, Johannesburg.
1904. §REUNERT, THEODORE, M.Inst.C.E. P.O. Box 92, Johannesburg.
1905. §Reyersbach, Louis. P.O. Box 149, Johannesburg.
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. (Pres. B, 1893 ; Council, 1893-99.) 29 Campden Hill-court, W.
1900. *Reynolds, Miss K. M. 4 Colinette-road, Putney, S.W.
1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1887.) 19 Lady Barn-road, Fallowfield, Manchester.
1906. §Reynolds, S. H. University College, Bristol.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1899. *RHYS, Professor JOHN, D.Sc. (Pres. H, 1900.) Jesus College, Oxford.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro 14, Modena, Italy.
1905. §Rich, Miss Florence. Roedean School, near Brighton.
1906. §Richards, Rev. A. W. 12 Bootham-terrace, York.
1869. *Richardson, Charles. 3 Cholmley-villas, Long Ditton, Surrey.
1882. †Richardson, Rev. George, M.A. Walcote, Winchester.
1884. *Richardson, George Straker. Isthmian Club, Piccadilly, W.
1889. †Richardson, Hugh, M.A. 12 St. Mary's, York.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1901. *Richardson, Owen Willans. Trinity College, Cambridge.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. §Riches, T. Harry. 8 Park-grove, Cardiff.
1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-street, S.W.
1902. §Ridgeway, William, M.A., Litt.D., Professor of Archeology in the University of Cambridge. Fen Ditton, Cambridge.
1894. †RIDLEY, E. P., F.G.S. (Local Sec. 1895.) Burwood, Westerfield-road, Ipswich.
1881. *Rigg, Arthur. 150 Blomfield-terrace, W.
1883. *RIGG, EDWARD, M.A. Royal Mint, E.
1892. †Rintoul, D., M.A. Clifton College, Bristol.
- *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.

Year of
Election.

1905. †Ritchie, Professor W., M.A. South African College, Cape Town.
 1903. *Rivers, W. H. R., M.D. St. John's College, Cambridge.
 1898. §Robb, Alfred A. Lisnabreeny House, Belfast.
 1902. *Roberts, Bruno. 30 St. George's-square, Regent's Park, N.W.
 1887. *Roberts, Evan. 30 St. George's-square, Regent's Park, N.W.
 1881. †Roberts, R. D., M.A., D.Sc., F.G.S. 4 Regent-street, Cambridge.
 1896. §Roberts, Thomas J. Ingleside, Park-road, Huyton, near Liverpool.
 1904. *Robertson, Miss Agnes. 9 Elsworth-terrace, Primrose Hill, N.W.
 1897. §ROBERTSON, Sir GEORGE S., K.C.S.I. (Pres. E, 1900.) 1 Pump-court, Temple, E.C.
 1905. †Robertson, Dr. G. W. Office of the Medical Officer of Health, Cape Town.
 1897. †Robertson, Professor J. W., C.M.G., LL.D. The Macdonald College, St. Anne de Bellevue; Quebec, Canada.
 1901. *Robertson, Robert, B.Sc., M.Inst.C.E. 154 West George-street, Glasgow.
 1905. †Robertson, Professor T. E. Transvaal Technical Institute, Johannesburg.
 1898. §Robinson, Charles E., M.Inst.C.E. Holne Cross, Ashburton, South Devon.
 1903. §Robinson, G. H. 1 Weld-road, Southport.
 1905. §Robinson, Harry. Ulster-chambers, Greenmarket-square, Cape Town.
 1887. §Robinson, Henry, M.Inst.C.E. Parliament-mansions, Victoria-street, S.W.
 1902. †Robinson, Herbert C. Holmfield, Aigburth, Liverpool.
 1906. §ROBINSON, H. H., M.A., F.I.C. 75 Finborough-road, S.W.
 1902. †Robinson, James, M.A., F.R.G.S. Dulwich College, Dulwich, S.E.
 1888. §Robinson, John, M.Inst.C.E. 8 Vicarage-terrace, Kendal.
 1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
 1905. †Robinson, Dr. Leland. 6 Victoria-walk, Woodstock, Cape Town.
 1899. *Robinson, Mark, M.Inst.C.E. 9 Belsize-grove, N.W.
 1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
 1904. †Robinson, Theodore R. 25 Campden Hill-gardens, W.
 1904. §Robinson, W. H. Kendrick House, Victoria-road, Penarth.
 1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
 1906. §Robson, J. Nalton. The Villa, Hull-road, York.
 1872. *Robson, William. 5 Gillsland-road, Merchiston, Edinburgh.
 1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
 1885. *Rodriguez, Epifanio. New Adelphi Chambers, 6 Robert-street, Adelphi, W.C.
 1905. §Roebuck, William Denison. 259 Hyde Park-road, Leeds.
 1905. §Rogers, A. W., M.A., F.G.S. South African Museum, Cape Town.
 1898. †ROGERS, BERTRAM, M.D. (Local Sec. 1898.) 11 York-place, Clifton, Bristol.
 1890. *Rogers, L. J., M.A., Professor of Mathematics in the University of Leeds. 15 Regent Park-avenue, Leeds.
 1906. §Rogers, Reginald A. P. 142 Leinster-road, Dublin.
 1884. *Rogers, Walter. 14 Gerald-road, S.W.
 1876. †ROLLIT, Sir A. K., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. 45 Belgrave-square, S.W.
 1905. †Rooth, Edward. Pretoria.
 1855. *ROSCOE, Sir HENRY ENFIELD, B.A., Ph.D., LL.D., D.C.L., F.R.S. (PRESIDENT, 1887; Pres. B, 1870, 1884; Council, 1874-81; Local Sec. 1861.) 10 Bramham-gardens, S.W.

Year of
Election.

1905. †Rose, Miss G. 45 De Pary's-avenue, Bedford.
 1905. †Rose, Miss G. Mabel. Ashley Lodge, Oxford.
 1883. *Rose, J. Holland, Litt.D. Ethandune, Parkside-gardens, Wimbleton, S.W.
 1905. †Rose, John G. Government Analytical Laboratory, Cape Town.
 1894. *ROSE, T. K., D.Sc., Chemist and Assayer to the Royal Mint. 6 Royal Mint, E.
 1905. *Rosedale, Rev. H. G., D.D., F.S.A. St. Peter's Vicarage, 13 Ladbroke-gardens, W.
 1905. *Rosedale, Rev. W. E. Willenhall, Staffordshire.
 1905. †Rosen, Jacob. 1 Hopkins-street, Yeoville, Transvaal.
 1905. †Rosen, Julius. Clifton Grange, Jarvie-street, Jeppestown, Transvaal.
 1900. †Rosenhain, Walter, B.A. 443 Gillott-road, Edgbaston, Birmingham.
 1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
 1902. §Ross, John Callender. 46 Holland-street, Campden-hill, W.
 1901. †ROSS, Colonel RONALD, C.B., F.R.S., Professor of Tropical Medicine and Parasitology in the University of Liverpool. 36 Bentley-road, Liverpool.
 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. Briarfield, Shibden, Halifax, Yorkshire.
 1865. *Rothera, George Bell. Hazlewood, Forest-grove, Nottingham.
 1905. †Rothkugel, R. Care of Messrs. D. Isaacs & Co., Cape Town.
 1901. *Rottenburg, Paul, LL.D. Care of Messrs. Leister, Bock, & Co., Glasgow.
 1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E.
 1884. *Rouse, M. L. Hollybank, Hayne-road, Beckenham.
 1905. §Rousselet, Charles F. 2 Pembridge-crescent, Bayswater, W.
 1861. †ROUTH, EDWARD J., M.A., Sc.D., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
 1883. †Rowan, Frederick John. 5 West Regent-street, Glasgow.
 1903. *Rowe, Arthur W., M.B., F.G.S. 1 Cecil-street, Margate.
 1890. †Rowley, Walter, M.Inst.C.E., F.S.A. Alderhill, Meanwood, Leeds.
 1906. §ROWNTREE, B. Seebohm. The Homestead, Clifton, York.
 1881. *ROWNTREE, JOHN S. Mount-villas, York.
 1881. *Rowntree, Joseph. 38 St. Mary's, York.
 1875. *RÜCKER, Sir A. W., M.A., D.Sc., F.R.S., Principal of the University of London (PRESIDENT, 1901 ; TRUSTEE, 1898- ; GENERAL TREASURER, 1891-98 ; Pres. A, 1894 ; Council, 1888-91). 19 Gledhow-gardens, South Kensington, S.W.
 1869. §RUDLER, F. W., I.S.O., F.G.S. 18 St. George's-road, Kilburn, N.W.
 1901. *Rudorf, C. C. G., Ph.D., B.Sc. 26 Weston-park, Crouch End, N.
 1905. *Ruffer, Marc Armand, C.M.G., M.A., M.D., B.Sc. Quarantine International Board, Alexandria.
 1905. §Ruffer, Mrs. Alexandria.
 1904. †Ruhemann, Dr. S. 3 Selwyn-gardens, Cambridge.
 1896. *Rundell, T. W., F.R.Met.Soc. 25 Castle-street, Liverpool.
 1904. †Russell, E. J., D.Sc., Professor of Chemistry in the South-Eastern Agricultural College, Wye, Kent.
 1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
 Russell, John. 39 Mountjoy-square, Dublin.
 1905. †Russell, Rev. J. M. Ardentrave, Tamboer's Kloof, Cape Town.
 1883. *Russell, J. W. 28 Staverton-road, Oxford.
 1852. *Russell, Norman Scott. Arts Club, Dover-street, W.

- Year of
Election.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., V.P.C.S. (Pres B, 1873 ; Council, 1873-80.) 34 Upper Hamilton-terrace, St. John's Wood, N.W.
1886. †Rust, Arthur. Eversleigh, Leicester.
1905. §Ryan, Pierce. Rosebank House, Rosebank, Cape Town.
1898. §Ryland, C. J. Southerndown House, Clifton, Bristol.
1906. *RYMER, Sir JOSEPH SYKES. The Mount, York.
1903. †SADLER, M. E., LL.D. (Pres. L, 1906), Professor of Education in the Victoria University, Manchester. Eastwood, Weybridge.
1883. †Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1903. §Sagar, J. The Poplars, Savile Park, Halifax.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1904. §SALTER, A. E., D.Sc., F.G.S. 20 Shell-road, Loampit Hill, Lewisham, S.E.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1901. †Samuel, John S., J.P., F.R.S.E. City Chambers, Glasgow.
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.
1903. †Sankey, Captain H. R., R.E. Bawmore, Bilton, Rugby.
1886. †Sankey, Percy E. 44 Russell-square, W.C.
1905. †Sargant, E. B. Quarry Hill, Reigate.
1896. *Sargant, Miss Ethel. Quarry Hill, Reigate.
1905. †Sargent, Miss Helen A., B.A. Huguenot College, Wellington, Cape Colony.
1886. †Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
1900. *SAUNDER, S. A. Fir Holt, Crowthorne, Berks.
1903. *Saunders, Miss E. R. Newnham College, Cambridge.
1901. †Sawers, W. D. 1 Athole Gardens-place, Glasgow.
1887. §SAYCE, Rev. A. H., M.A., D.D. (Pres. H, 1887), Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1906. §Sayer, Dr. Ettie. 39 Brook-street, W.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1903. §SCARISBRICK, Sir CHARLES, J.P. Scarisbrick Lodge, Southport.
1903. †Scarisbrick, Lady. Scarisbrick Lodge, Southport.
1879. *SCHÄFER, E. A., LL.D., D.Sc., F.R.S., M.R.C.S. (GEN. SEC. 1895-1900 ; Pres. I, 1894 ; Council, 1887-93), Professor of Physiology in the University of Edinburgh.
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.)
1905. †Scholer, W. Peter. *Transvaal Technical Institute, Johannesburg.*
1885. §Scholes, L. Ivy Cottage, Parade, Parkgate, Cheshire.
1905. †Schonland, S., Ph.D. Albany Museum, Grahamstown, Cape Colony.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S. (Pres. A, 1892 ; Council, 1887-93), Professor of Physics in the Victoria University, Manchester. Kent House, Victoria Park, Manchester.
1905. †Sclander, J. E. P.O. Box 465, Cape Town.

Year of
Election.

1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S. (GENERAL SECRETARY, 1876-81; Pres. D, 1875; Council, 1864-67, 1872-75.) Odiham Priory, Winchfield.
1883. *SCLATER, W. LUTLEY, M.A., F.Z.S. South African Museum, Cape Town.
1905. †Sclater, Mrs. W. L. Crossroads, Baker-road, Wynberg, Cape Colony.
1881. *SCOTT, ALEXANDER, M.A., D.Sc., F.R.S., F.C.S. Royal Institution, Albemarle-street, W.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1889. *SCOTT, D. H., M.A., Ph.D., F.R.S., F.L.S. (GENERAL SECRETARY, 1900-03; Pres. K, 1896.) East Oakley House, Oakley, Hants.
1857. *SCOTT, ROBERT H., M.A., D.Sc., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.
1884. *Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.
1902. †Scott, William R. The University, St. Andrews, Scotland.
1895. †Scott-Elliot, Professor G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.
1883. †Scrivener, Mrs. Haglis House, Wendover.
1895. §Scull, Miss E. M. L. St. Edmund's, 10 Worsley-road, Hampstead, N.W.
1890. *Searle, G. F. C., M.A., F.R.S. Wyncote, Hills-road, Cambridge.
1880. †SEDGWICK, ADAM, M.A., F.R.S. (Pres. D, 1899.) 4 Cranmer-road, Cambridge.
1905. †Sedgwick, C. F. Strand-street, Cape Town.
1906. *See, T. J. J., Ph.D. Naval Observatory, Mare Island, California.
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. 3 Holland Park-court, Holland Park-gardens, W.
1904. †Sell, W. J. 19 Lensfield-road, Cambridge.
1904. †Sella, Professor Alfonso. Instituto Fisico, Rome.
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. 15 Heath-mansions, Hampstead, N.W.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1905. †Serrurier, Louis C. Ashley, Sea Point, Cape Town.
1901. †Service, Robert. Janefield Park, Maxwelltown, Dumfries.
1895. *Seton-Karr, H. W. 31 Lingfield-road, Wimbledon, Surrey.
1892. *SEWARD, A. C., M.A., F.R.S., F.G.S. (Pres. K, 1903; Council, 1901-; Local Sec. 1904), Professor of Botany in the University of Cambridge. Westfield, Huntingdon-road, Cambridge.
1904. †Sewell, R. B. Seymour. Christ's College, Cambridge.
1899. §Seymour, Henry J., B.A., F.G.S. St. Peter's, Ailesbury-road, Dublin.
1891. †Shackell, F. W. 191 Newport-road, Cardiff.
1905. *Shackleford, W. C., M.Inst.M.E. County Club, Lancaster.
1904. †Shackleton, Ernest H., F.R.G.S. 14 South Learmonth-gardens, Edinburgh.
1902. †SHAFFESBURY, The Right Hon. the Earl of, D.L. Belfast Castle, Belfast.
1906. §Shann, Frederick. 6 St. Leonard's, York.
1878. †SHARP, DAVID, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1904. †Sharpe, Mrs. E. M. Drumna House, Whetstone, N.

Year of
Election.

1904. †Sharpe, Walter. Drumna House, Whetstone, N.
 1904. †Sharples, George. 181 Great Cheetham-street West, Higher
 Broughton, Manchester.
 1889. *Shaw, Mrs. M. S., B.Sc. Sydenham Damard Rectory, Tavistock.
 1883. *SHAW, W. N., M.A., D.Sc., F.R.S. (Council, 1895-1900, 1904- .)
 Meteorological Office, 63 Victoria-street, S.W.
 1883. †Shaw, Mrs. W. N. 10 Moreton-gardens, South Kensington, S.W.
 1904. †Shaw-Phillips, Miss. 19 Camden-crescent, Bath.
 1903. †Shaw-Phillips, T., J.P. 19 Camden-crescent, Bath.
 1905. †Shenstone, Miss A. Sutton Hall, Barcombe, Lewes.
 1905. †Shenstone, Mrs. A. E. G. Sutton Hall, Barcombe, Lewes.
 1865. †Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
 1881. †SHENSTONE, W. A., F.R.S. Clifton College, Bristol.
 1900. §Sheppard, Thomas, F.G.S. The Municipal Museum, Hull.
 1905. †Sheridan, Dr. Norman. 96 Francis-street, Bellevue, Johannesburg.
 1883. †Sherlock, David. Rahan Lodge, Tullamore, Dublin.
 1883. †Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
 1896. §SHERRINGTON, C. S., M.D., F.R.S. (Pres. I, 1904), Professor of
 Physiology in the University of Liverpool. 16 Grove-park,
 Liverpool.
 1888. *Shickle, Rev. C. W., M.A., F.S.A. St. John's Hospital, Bath.
 1902. *Shillington, T. Foulkes, J.P. Dromart, Antrim-road, Belfast.
 1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, E.C.
 1887. *SHIPLEY, ARTHUR E., M.A., F.R.S. (Council, 1904- .) Christ's
 College, Cambridge.
 1870. *SHOOLBRED, J. N., B.A., M.Inst.C.E. 47 Victoria-street, S.W.
 1897. †SHORE, Dr. LEWIS E. St. John's College, Cambridge.
 1882. †SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at
 St. Bartholomew's Hospital. 6 Kingswood-road, Upper Nor-
 wood, S.E.
 1901. †Short, Peter M., B.Sc. 1 Holmdene-avenue, Herne Hill, S.E.
 1904. *Shrubsall, F. C., M.A., M.D. Brompton Hospital, S.W.
 1889. †Sibley, Walter K., M.A., M.D. The Mansions, 70 Duke-street, W.
 1902. †Siddons, A. W. Harrow-on-the-Hill, Middlesex.
 1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
 1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
 Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
 1873. *SIEMENS, ALEXANDER, M.Inst.C.E. 12 Queen Anne's-gate, S.W.
 1905. †Siemens, Mrs. A. 12 Queen Anne's-gate, S.W.
 1903. *Silberrad, Dr. Oswald. Experimental Establishment, Royal Arsenal,
 Woolwich.
 1871. *SIMPSON, Sir ALEXANDER R., M.D., Emeritus Professor of Mid-
 wifery in the University of Edinburgh. 52 Queen-street,
 Edinburgh.
 1863. †Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
 1901. *Simpson, Professor J. Y., M.A., D.Sc., F.R.S.E. 52 Queen-street,
 Edinburgh.
 1894. §Simpson, Thomas, F.R.G.S. Fennymere, Castle Bar, Ealing, W.
 1896. *Simpson, W., F.G.S. Catteral Hall, Settle, Yorkshire.
 1874. †SINCLAIR, Right Hon. THOMAS (Local Sec. 1874). Dunedin,
 Belfast.
 1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola,
 Calcutta.
 1905. *Sjogren, Professor H. Natural History Museum, Stockholm,
 Sweden.
 1902. †Skeffington, J. B., M.A., LL.D. Waterford.
 1906. §Skerry, H. A. St. Paul's-square, York.

Year of
Election.

1883. †Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
 1898. †SKINNER, SIDNEY, M.A. (Local Sec. 1904.) South-Western
 Polytechnic, Manresa-road, Chelsea, S.W.
 1905. §Skyrme, C. G. 28 Norman-road, St. Leonard's-on-Sea.
 1905. †Slater, Dr. H. B. 75 Bree-street, Johannesburg.
 1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
 1887. †Small, Evan W., M.A., B.Sc., F.G.S. The Mount, Radbourne-
 street, Derby.
 1887. §Small, William. Lincoln-circus, The Park, Nottingham.
 1903. *Smallman, Raleigh S. Wressil Lodge, Wimbledon Common, S.W.
 1904. †Smart, Edward. Benview, Craigie, Perth, N.B.
 1889. *SMART, Professor WILLIAM, LL.D. (Pres. F, 1904.) Nunholme,
 Downhill, Glasgow.
 1902. §Smedley, Miss Ida. 11 Mecklenburgh-square, W.C.
 1905. †Smith, Miss Adelaide. Huguenot College, Wellington, Cape
 Colony.
 1897. †Smith, Andrew, Principal of the Veterinary College, Toronto,
 Canada.
 1901. *Smith, Miss Annie Lorrain. 20 Talgarth-road, West Kensing-
 ton, W.
 1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club,
 Pall Mall, S.W.
 1873. †Smith, C. Sidney College, Cambridge.
 1905. †Smith, C. H. Fletcher's-chambers, Cape Town.
 1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Obser-
 vatory, Kodaikanal, South India.
 1887. *Smith, Charles. 739 Rochdale-road, Manchester.
 1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
 1900. §Smith, E. J. Grange House, Westgate Hill, Bradford.
 1901. §Smith, F. B. Care of A. Croxton Smith, Esq., Burlington House,
 Wandle-road, Upper Tooting, S.W.
 1866. *Smith, F. C. Bank, Nottingham.
 1897. †Smith, G. Elliot, M.D. St. John's College, Cambridge.
 1903. *Smith, H. B. Lees. 16 Park-terrace, Oxford.
 1889. *Smith, H. Llewellyn, C.B., B.A., B.Sc., F.S.S. Board of Trade,
 S.W.
 1860. *Smith, Heywood, M.A., M.D. 25 Welbeck-street, Cavendish-
 square, W.
 1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
 1902. †Smith, J. Lorrain, M.D., Professor of Pathology in the Victoria
 University, Manchester.
 1903. *Smith, James. Pinewood, Crathes, Aberdeen.
 Smith, John Peter George. Sweeney Cliff, Coalport, Iron Bridge,
 Shropshire.
 1894. §Smith, T. Walrond. Care of Frank Henderson, Esq., Shirley,
 Station-road, Sidcup, Kent.
 1896. *Smith, Rev. W. Hodson. Newquay, Cornwall.
 1885. *Smith, Watson. 34 Upper Park-road, Haverstock Hill, N.W.
 1883. †SMITHELLS, ARTHUR, B.Sc., F.R.S. (Local Sec. 1890), Professor
 of Chemistry in the University of Leeds.
 1906. §Smurthwaite, Thomas E. 134 Mortimer-road, Kensal Rise, W.
 1905. §Smuts, C. P.O. Box 1088, Johannesburg.
 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. Balholm, Lathom-road, South-
 port.
 1905. §SODDY, F. The University, Glasgow.

Year of
Election.

1905. §Sollas, Miss I. B. J. Newnham College, Cambridge.
1879. *SOLLAS, W. J., M.A., Sc.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1900 ; Council, 1900-03), Professor of Geology in the University of Oxford. 173 Woodstock-road, Oxford.
1905. †Solomon, R. Stuart. Care of Messrs. R. M. Moss & Co., Cape Town.
1892. *SOMERVALE, ALEXANDER. The Museum, Torquay.
1900. *SOMERVILLE, W., D.Sc., F.L.S., Sibthorpe Professor of Rural Economy in the University of Oxford. 121 Banbury-road, Oxford.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. (Pres. C, 1880 ; Council, 1879-86 ; Local Sec. 1879.) Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Ranmoor, Sheffield.
1901. †Sorley, Robert. The Firs, Partickhill, Glasgow.
1903. †Soulby, R. M. Sea Holm, Westbourne-road, Birkdale, Lancashire.
1903. †Southall, Henry T. The Graig, Ross, Herefordshire.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1883. †Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1905. †Spencer, Charles Hugh. P.O. Box 2, Maraisburg, Transvaal.
1889. *Spencer, John W. Impney Hall, Droitwich, Worcester.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen-park, High-bury, N.
1894. †Spiers, A. H. Gresham's School, Holt, Norfolk.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, N.
1864. *Spottiswoode, W. Hugh, F.C.S. 91 Savoy-court, Strand, W.C.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1905. †Squire, Mrs. Clarendon House, 30 St. John's Wood-park, N.W.
1888. *Stacy, J. Sargeant. 164 Shoreditch, E.C.
1903. †Stallworthy, Rev. George B. The Manse, Hindhead, Haslemere, Surrey.
1883. *Stanford, Edward, F.R.G.S. 12-14 Long-acre, W.C.
1905. †Stanley, Professor George H. Transvaal Technical Institute, Johannesburg.
1881. *Stanley, William Ford, J.P., F.G.S. Cumberlow, South Norwood, S.E.
1883. †Stanley, Mrs. Cumberlow, South Norwood, S.E.
1894. *STANSFIELD, ALFRED, D.Sc. McGill University, Montreal, Canada.
1900. *Stansfield, H., B.Sc. 20 Every-street, Ancoats, Manchester.
1905. §Stanwell, H. B. South African College School, Cape Town.
1905. †Stanwell, Dr. St. John. P.O. Box 1050, Johannesburg.
1905. †Stapleton, Frederick. Control and Audit Office, Cape Town.
1905. *Starkey, A. H. 24 Greenhead-road, Huddersfield.
1899. †STARLING, E. H., M.D., F.R.S., Professor of Physiology in University College, London, W.C.
1899. §Statham, William. The Redings, Totteridge, Herts.
1898. †Stather, J. W., F.G.S. Brookside, Newland Park, Hull.
- Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. Red Barns, Freshfield, Liverpool.
1900. *Stead, J. E., F.R.S. Laboratory and Assay Office, Middlesbrough.
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. 8 Playfair-mansions, Queen's Club-gardens, W.
1905. †Stebbins, Miss Inez F., B.A. Huguenot College, Wellington, Cape Town.

Year of
Election.

1905. †Stephen, J. M. Invernegie, Sea Point, Cape Colony.
 1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
 1902. †Stephenson, G. Culin, Glasnevin, Dublin.
 1906. §Stevens, Miss C. O. The Red House, Bradfield, Reading.
 1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpill, R.S.O.
 1900. †STEVENS, FREDERICK (Local Sec. 1900). Town Clerk's Office, Bradford.
 1890. *Steward, Rev. Charles J., F.R.M.S. The Cedars, Anglesea-road, Ipswich.
 1885. *Stewart, Rev. Alexander, M.D., LL.D. Murtle, Aberdeen.
 1905. §Stewart, A. F. 28 South-street, Halifax, Nova Scotia, Canada.
 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.
 1905. †Stewart, Charles. Meteorological Commission, Cape Town.
 1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
 1901. *Stewart, John Joseph, M.A., B.Sc. 35 Stow Park-avenue, Newport, Monmouthshire.
 1901. *Stewart, Thomas. St. George's-chambers, Cape Town.
 1905. †Steyn, Dr. G. H. Kandahar, Salt River, Cape Colony.
 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.
 1904. §Stobbs, J. T. Dunelm, Basford Park, Stoke-on-Trent.
 1906. *Stobo, Mrs. Annie. Somerset House, Garelochhead, Dumbartonshire, N.B.
 1901. *Stobo, Thomas. Somerset House, Garelochhead, Dumbartonshire, N.B.
 1865. *Stock, Joseph S. St. Mildred's, Walmer.
 1883. *STOCKER, W. N., M.A. Brasenose College, Oxford.
 1898. *Stokes, Professor George J., M.A. 5 Fernhurst-villas, College-road, Cork.
 1899. *Stone, Rev. F. J. Radley College, Abingdon.
 1874. †Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
 1905. †Stoneman, Miss Bertha, D.Sc. Huguenot College, Wellington, Cape Colony.
 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. 30 Ledbury-road, Bayswater, W.
 1878. *Stoney, G. Gerald. Oakley, Heaton-road, Newcastle-upon-Tyne.
 1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. (Pres. A, 1897.) 30 Ledbury-road, Bayswater, W.
 1903. *Stopes, Miss Marie, Ph.D., B.Sc. 53 Stanley-gardens, Haverstock Hill, N.W.
 1883. †Stopes, Mrs. 53 Stanley-gardens, Haverstock Hill, N.W.
 1887. *Storey, H. L. Bailrigg, Lancaster.
 1884. †Storrs, George H. Gorse Hall, Stalybridge.
 1888. *Stothert, Percy K. Woolley Grange, Bradford-on-Avon, Wilts.
 1905. *Stott, Clement H. Pietermaritzburg, Natal.
 1905. §Stower, Miss Alice. 34 Palace Gardens-terrace, W.
 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. (Pres. E, 1875; Council, 1871-75.) 69 Lancaster-gate, Hyde Park, W.
 1881. †STRAHAN, AUBREY, M.A., F.R.S., F.G.S. (Pres. C, 1904.) Geological Museum, Jermyn-street, S.W.

Year of
Election.

1905. §Strange, Harold F. P.O. Box 2527, Johannesburg.
1881. †STRANGWAYS, C. FOX, F.G.S. Kylemore, Hollycroft-avenue,
West Hampstead, N.W.
1906. *Stromeyer, C. E. 9 Mount-street, Albert-square, Manchester.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M. 3 Champion-park, Denmark Hill, S.E.
1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the Armstrong
College, Newcastle-upon-Tyne.
1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the University
of Leeds.
1905. †Struben, Mrs. A. P.O. Box 1228, Pretoria.
1876. *Stuart, Charles Maddock, M.A. St. Dunstan's College, Catford,
S.E.
1872. *Stuart, Rev. Edward A., M.A. 5 Prince's-square, W.
1885. †Stump, Edward C. Malmesbury, Polefield, Blackley, Manchester.
1879. *Styring, Robert. Brinkcliffe Tower, Sheffield.
1891. *Sudborough, Professor J. J., Ph.D., D.Sc. University College of
Wales, Aberystwyth.
1902. §Sully, H. T. Scottish Widows'-buildings, Bristol.
1898. §Sully, T. N. Avalon House, Queen's-road, Weston-super-Mare.
1905. †Summer, A. B. Ollersett Booyseux, Transvaal.
1887. *Sumpner, W. E., D.Sc. Technical School, Suffolk-street, Bir-
mingham.
1903. †Swallow, Rev. R. D., M.A. Chigwell School, Essex.
1905. †Swan, Miss Hilda. 58 Holland Park, W.
1881. §SWAN, Sir JOSEPH WILSON, M.A., D.Sc., F.R.S. 58 Holland Park, W.
1905. †Swan, Miss Mary E. 58 Holland-park, W.
1897. †Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1887. §SWINBURNE, JAMES, F.R.S., 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. 22 Oxford-road, Birkdale, Southport.
1895. †Sykes, E. R., B.A. 3 Gray's Inn-place, W.C.
1902. *Sykes, Miss Ella C. Elcombs, Lyndhurst, Hampshire.
1887. *Sykes, George, H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elm-
bourne-road, Tooting Common, S.W.
1896. *Sykes, Mark L., F.R.M.S. 10 Headingley-avenue, Leeds.
1902. *Sykes, Major P. Molesworth, C.M.G. Elcombs, Lyndhurst,
Hampshire.
1906. §Sykes, T. P., M.A. 4 Gathorne-street, Great Horton, Bradford.
1905. §Symington, C., M.B. Railway Medical Office, De Aar, Cape
Colony.
1903. §Symington, Howard W. Brooklands, Market Harborough.
1885. †SYMINGTON, JOHNSON, M.D., F.R.S., F.R.S.E. (Pres. H, 1903),
Professor of Anatomy in Queen's College, Belfast.
1905. †Symmes, H. C. P.O. Box 3902, Johannesburg.
1896. †Tabor, J. M. Holmwood, Harringay Park, Crouch End, N.
1904. §Tallack, H. T. Clovelly, Birdhurst-road, South Croydon.
1903. *Tanner, Miss Ellen G. 48 Campden House-court, Gloucester-
walk, W.
1890. †TANNER, H. W. LLOYD, D.Sc., F.R.S. (Local Sec. 1891), Professor
of Mathematics and Astronomy in University College, Cardiff.
1892. *Tansley, Arthur G., M.A., F.L.S. University College, W.C.
1883. *Tapscott, R. Lethbridge, F.R.A.S. 62 Croxteth-road, Liverpool.
1861. *Tarratt, Henry W. 332 Marylebone-road, N.W.

Year of
Election.

1902. †Tate, Miss. Rantalard, Whitehouse, Belfast.
 1901. †Taylor, Benson. 22 Hayburn-crescent, Partick, Glasgow.
 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.
 1906. §Taylor, H. Dennis. Stancliffe, Mount-villas, York.
 1884. *TAYLOR, H. M., M.A., F.R.S. Trinity College, Cambridge.
 1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
 1860. *Taylor, John, M.Inst.C.E., F.G.S. 6 Queen Street-place, E.C.
 1906. §Taylor, Miss M. R. Newstead, Blundellsands.
 1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
 1895. †Taylor, W. A., M.A., F.R.S.E. 3 East Mayfield, Edinburgh.
 1894. *Taylor, W. W., M.A. 66 St. John's-road, Oxford.
 1901. §Taylor, William. 57 Sparkenhoe-street, Leicester.
 1903. †Taylor, William. 61 Cambridge-road, Southport.
 1901. *Teacher, John H., M.B. 32 Kingsborough-gardens, Glasgow.
 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. (Pres. C, 1893 ; Council,
 1894-1900), Director of the Geological Survey of the United
 Kingdom. The Museum, Jermyn-street, S.W.
 1906. §Teape, Rev. W. M. South Hylton Vicarage, Sunderland.
 1898. §Tebb, Robert Palmer. Enderfield, Chislehurst, Kent.
 1879. †Temple, Lieutenant G. T., R.N., F.R.G.S. Solheim, Cumberland
 Park, Acton, W.
 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, LL.D., Professor of Anatomy in Uni-
 versity College, London, W.C.
 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. (Pres. D, 1888 ; Pres. K,
 1895 ; Council, 1885-89, 1895-1900.) The Ferns, Witcombe,
 Gloucester.
 1906. §Thoday, D. Trinity College, Cambridge.
 1870. †Thom, Colonel Robert Wilson, J.P. Brooklands, Lord-street
 West, Southport.
 1891. *Thomas, Miss Clara. Penurrig, Builth.
 1903. †Thomas, Miss Ethel N. 3 Downe-mansions, Gondar-gardens,
 West Hampstead, N.W.
 1880. *Thomas, Joseph William, F.C.S. Overdale, Shortlands, Kent.
 1899. *Thomas, Mrs. J. W. Overdale, Shortlands, Kent.
 1902. §Thomas, Miss M. B. 200 Bristol-road, Birmingham.
 1904. †Thomas, Northcote W. 7 Coptic-street, W.C.
 1883. †Thomas, Thomas H. 45 The Walk, Cardiff.
 1904. *Thomas, William. Bryn-heulog. Merthyr Tydfil.
 1891. *Thompson, Beeby, F.C.S., F.G.S. 67 Victoria-road, Northampton.
 1888. *Thompson, Claude M., M.A., D.Sc., Professor of Chemistry in
 University College, Cardiff. 38 Park-place, Cardiff.
 1885. †THOMPSON, D'ARCY W., B.A., C.B., Professor of Zoology in Univer-
 sity College, Dundee.
 1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop.
 1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
 1904. *Thompson, G. R., B.Sc., Professor of Mining in the University of
 Leeds.

Year of
Election.

1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.
1905. †Thompson, James. P.O. Box 312, Johannesburg.
1861. *Thompson, Joseph. Riversdale, Wilmslow, Cheshire.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1876. †Thompson, Silvanus Phillips, B.A., D.Sc., F.R.S., F.R.A.S. (Council, 1897-99), Principal and Professor of Physics in the City and Guilds of London Technical College, Finsbury, E.C.
1883. *Thompson, T. H. Oldfield Lodge, Gray-road, Bowdon, Cheshire.
1896. *Thompson, W. H., M.D., D.Sc., King's Professor of Institutes of Medicine (Physiology) in Trinity College, Dublin. 14 Hatch-street, Dublin.
1905. †Thompson, William. Parkside, Doncaster-road, Rotherham.
1906. §Thompson, W. F. H. Old Nunthorpe, York.
1894. †Thomson, Arthur, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1906. §Thomson, F. Ross, F.G.S. Hensill, Hawkhurst, Kent.
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. (Pres. A, 1896; Council 1893-95), Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1902. †Thomson, J. Stuart. Marine Biological Laboratory, Plymouth.
1901. †Thomson, Dr. J. T. Kilpatrick. 148 Norfolk-street, Glasgow.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1871. *Thomson, John Millar, LL.D., F.R.S. (Council, 1895-1901), Professor of Chemistry in King's College, London. 9 Campden Hill-gardens, W.
1874. §Thomson, William, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1905. *Thorneley, Miss L. R. Nunclose, Grassendale, Liverpool.
1906. §Thornely, Miss A. M. M. Oaklands, Bowdon, Cheshire.
1898. §Thornton, W. M., D.Sc., Professor of Electrical Engineering in the Armstrong College, Newcastle-on-Tyne.
1902. †Thornycroft, Sir John I., F.R.S., M.Inst.C.E. Eyot Villa, Chiswick Mall, W.
1903. †Thorp, Edward. 87 Southbank-road, Southport.
1881. †Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. 37 Pleasant-street, New Brighton, Cheshire.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.
1898. †Thorpe, Jocelyn Field, Ph.D. Owens College, Manchester.
1871. †Thorpe, T. E., C.B., Ph.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1890; Council, 1886-92), Principal of the Government Laboratories, Clement's Inn-passage, W.C.
1883. §Threlfall, Henry Singleton, J.P. 1 London-street, Southport.
1899. §Threlfall, Richard, M.A., F.R.S. 30 George-road, Edgbaston, Birmingham.
1896. §Thrift, William Edward, M.A., Professor of Natural and Experimental Philosophy in the University of Dublin. 80 Grosvenor square, Rathmines, Dublin.
1904. §Thurston, Edgar. Government Museum, Madras.
1889. †Thys, Colonel Albert. 9 Rue Briderode, Brussels.
1873. *Tiddeman, R. H., M.A., F.G.S. 175 Banbury-road, Oxford.
1905. §Tietz, Heinrich, B.A., Ph.D. South African College, Cape Town.

Year of
Election.

1874. †TILDEN, WILLIAM A., D.Sc., F.R.S., F.C.S. (Pres. B, 1888; Council, 1898-1904), Professor of Chemistry in the Royal College of Science, London. The Oaks, Northwood, Middlesex.
1896. §Timmis, Thomas Sutton. Cleveley, Allerton, Liverpool.
1899. †Tims, H. W. Marett, M.A., M.D., F.L.S. Deepdene, Cavendish-avenue, Cambridge.
1902. §Tipper, Charles J. R., B.Sc. 21 Greenside, Kendal.
1905. §Tippett, A. M., M.Inst.C.E. Cape Government Railways, Cape Town.
1900. §Tocher, J. F., F.I.C. 5 Chapel-street, Peterhead, N.B.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1905. †Tonkin, Samuel. Rosebank, near Cape Town.
1875. †Torr, Charles Hawley. 35 Burlington-road, Sherwood, Nottingham.
1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.
1901. †Townsend, J. S. E., M.A., F.R.S., Professor of Physics in the University of Oxford. New College, Oxford.
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., Provost of Trinity College, Dublin, 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. (Pres. D, 1900.) The Bush, Colinton, Midlothian.
1902. †Travers, Ernest J. Dunmurry, Co. Antrim.
1884. †Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1887. *Trench-Gascoigne, Mrs. F. R. Lotherton Hall, Parlington, Aberford, Leeds.
1903. †Trenchard, Hugh. The Firs, Clay Hill, Enfield.
1905. §TREVOR-BATTYE, A., M.A., F.L.S., F.R.G.S. Chilbolton, Stockbridge, R.S.O.
1871. †TRIMEN, ROLAND, M.A., F.R.S., F.L.S., F.Z.S. Ovingdean, King Charles-road, Surbiton Hill.
1902. §Tristram, Rev. J. F., M.A., B.Sc. 20 Chandos-road, Chorlton-cum-Hardy, Manchester.
1884. *Trotter, Alexander Pelham. 8 Richmond-terrace, Whitehall, S.W.
1887. *TROUTON, FREDERICK T., M.A., Sc.D., F.R.S., Professor of Physics in University College, W.C.
1898. §Trow, Albert Howard, D.Sc., F.L.S., Professor of Botany in University College, Cardiff. 50 Clive-road, Penarth.
1885. *Tubby, A. H., F.R.C.S. 25 Weymouth-street, Portland-place, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1905. §Turmeau, Charles. Claremont, Victoria Park, Wavertree, Liverpool.
1901. §Turnbull, Robert, B.Sc. Department of Agriculture and Technical Instruction, Dublin.
1893. §TURNER, DAWSON, M.B. 37 George-square, Edinburgh.
1905. †Turner, Dr. G. 54 Government-buildings, Pretoria.
1894. *TURNER, H. H., M.A., D.Sc., F.R.S., F.R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.
1905. §Turner, Rev. Thomas. St. Saviour's Vicarage, 50 Fitzroy-street, W.
1886. *TURNER, THOMAS, M.Sc., A.R.S.M., F.I.C., Professor of Metallurgy in the University of Birmingham. 355 Bristol-road, Edgbaston, Birmingham.

Year of
Election.

1863. *TURNER, Sir WILLIAM, K.C.B., LL.D., D.C.L., F.R.S., F.R.S.E.
(PRESIDENT, 1900 ; Pres. H, 1889, 1897), Principal of the
University of Edinburgh. 6 Eton-terrace, Edinburgh.
1890. *Turpin, G. S., M.A., D.Sc. High School, Nottingham.
1886. *Twigg, G. H. Ludgate-hill, Birmingham.
1899. †Twisden, John R., M.A. 14 Gray's Inn-square, W.C.
1865. §TYLOR, EDWARD BURNETT, D.C.L., LL.D., F.R.S. (Pres. H, 1884 ;
Council, 1896-1902), Professor of Anthropology in the Univer-
sity of Oxford. Museum House, Oxford.
1883. †Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane,
Stratford, E.
1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1903. †Underwood, Captain J. C. 60 Scarisbrick New-road, Southport.
1885. §Unwin, Howard. 1 Newton-grove, Bedford Park, Chiswick, W.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *UNWIN, W. C., F.R.S., M.Inst.C.E. (Pres. G, 1892 ; Council,
1892-99.) 7 Palace Gate-mansions, Kensington, W.
1902. §Ussher, R. J. Cappagh House, Cappagh, Co. Waterford.
1880. †USSHER, W. A. E., F.G.S. 28 Jermyn-street, S.W.
1905. §Uttley, E. A., Electrical Inspector to the Rhodesian Government,
Bulawayo.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1905. †Van der Byl, J. A. P.O., Irene, Transvaal.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road,
Bromley, Kent.
1865. *VARLEY, S. ALFRED. Arrow Works, Jackson-road, Holloway, N.
1903. †Varwell, H. B. 2 Pennsylvania-park, Exeter.
1895. §Vaughan, D. T. Gwynne. Botanical Laboratory, The University,
Glasgow.
1905. †Vaughan, E. L. Eton College, Windsor.
1881. §VELEY, V. H., M.A., D.Sc., F.R.S. 20 Bradmore-road, Oxford.
1873. *VERNEY, Sir EDMUND H., Bart., F.R.G.S. Claydon House, Wins-
low, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1904. *Vernon, H. M., M.A., M.D. 3 Bevington-road, Oxford.
1896. *Vernon, Thomas T. Wyborne Gate, Birkdale, Southport.
1896. *Vernon, William. Wyborne Gate, Birkdale, Southport.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Carlisle Lodge, Rickmans-
worth.
1906. *Vincent, J. H., M.A., D.Sc. L.C.C. Paddington Technical Institute,
Saltram-crescent, W.
1899. *VINCENT, Professor SWALE, M.B. Physiological Laboratory, Uni-
versity of Manitoba, Winnipeg, Canada.
1883. *VINES, SYDNEY HOWARD, M.A., D.Sc., F.R.S., F.L.S. (Pres. K,
1900 ; Council, 1894-97), Professor of Botany in the University
of Oxford. Headington Hill, Oxford.
1902. §Vinycomb, T. B. Riverside, Holywood, Co. Down.
1904. §Vólterra, Professor Vito. Regia Universita, Rome.
1904. §Wace, A. J. B. Pembroke College, Cambridge.
1886. *Wackrill, Samuel Thomas, J.P. 38 Portland-street, Leamington.
1902. †Waddell, Rev. C. H. The Vicarage, Saintfield.

Year of
Election.

1888. †Wadworth, H. A. Breinton Court, near Hereford.
 1890. §WAGER, HAROLD W. T., F.R.S., F.L.S. (Pres. K, 1905.) Hendre,
Horsforth-lane, Far Headingley, Leeds.
 1900. †Wagstaff, C. J. L., B.A. Grafton House, Oundle.
 1902. †Wainwright, Joel. Finchwood, Marple Bridge, Stockport.
 1906. §Wakefield, Charles. Heslington House, York.
 1905. §Wakefield, Captain E. W. Strickland Gate House, Kendal.
 1894. †WALFORD, EDWIN A., F.G.S. 21 West Bar, Banbury.
 1882. *Walkden, Samuel, F.R.Met.S. The Cottage, Whitchurch, Tavis-
tock.
 1893. §Walker, Alfred O., F.L.S. Ulcombe-place, Maidstone, Kent.
 1890. †Walker, A. Tannett. The Elms, Weetwood, Leeds.
 1901. *Walker, Archibald, M.A., F.I.C. 7 Crown-terrace, Glasgow.
 1897. *WALKER, B. E., D.C.L., F.G.S. (Local Sec. 1897.) Canadian Bank
of Commerce, Toronto, Canada.
 1904. §Walker, E. R. Nightingales, Adlington, Lancashire.
 1891. †Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
 1905. †Walker, G. M. Lloyd's-buildings, Burg-street, Cape Town.
 1894. *WALKER, G. T., M.A., D.Sc., F.R.S., F.R.A.S. Meteorological
Office, Simla, India.
 1897. †Walker, George Blake. Tankersley Grange, near Barnsley.
 1906. †Walker, J. F. E. Gelson, B.A. 45 Bootham, York.
 1866. *WALKER, J. FRANCIS, M.A., F.G.S., F.L.S. 45 Bootham, York.
 1894. *WALKER, JAMES, M.A. 30 Norham-gardens, Oxford.
 1906. §Walker, Dr. Jamieson. Kilcaddew, Killygordon, Donegal.
 1888. †Walker, Sydney F. 1 Bloomfield-crescent, Bath.
 1896. §Walker, Colonel William Hall, M.P. Gateacre, Liverpool.
 1883. †Wall, Henry. 14 Park-road, Southport.
 1863. †WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S.
(Pres. D, 1876 ; Council, 1870-72.) Broadstone, Wimborne,
Dorset.
 1905. †Wallace, R. W. 2 Harcourt-buildings, Temple, E.C.
 1901. †Wallace, William, M.A., M.D. 25 Newton-place. Glasgow.
 1887. *WALLER, AUGUSTUS D., M.D., F.R.S. 32 Grove End-road, N.W.
 1905. §Waller, Mrs. 32 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.
 1894. *WALMSLEY, A. T., M.Inst.C.E. 9 Victoria-street, Westminster,
S.W.
 1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell,
E.C.
 1903. †Walsh, W. T. H. Toynbee Hall, Whitechapel, E.
 1895. †WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall,
Thetford.
 1902. *Walter, Miss L. Edna. 38 Woodberry-grove, Finsbury Park, N.
 1904. *Walters, William, jun. Etheldreda House, Exning, Newmarket.
 1904. †Ward, A. H. M., B.A. Lenoxvale, Belfast.
 1887. †WARD, A. W., M.A., Litt.D., Master of Peterhouse, Cambridge.
 1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
 1880. *Ward, J. Wesney. 4 Chepstow-mansions, Pembroke-villas, Bays-
water, W.
 1874. §Ward, John, J.P., F.S.A. Lenoxvale, Belfast.
 1858. †Wardle, Sir Thomas, F.G.S. St. Edward-street, Leek, Stafford-
shire.
 1878. †WARINGTON, ROBERT, F.R.S., F.C.S. High Bank, Harpenden,
St. Albans, Herts.

Year of
Election.

1905. §Warlow, Dr. G. B. 15 Hamilton-street, Birkenhead.
 1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
 1896. †Warrand, Major-General, R.E. Westhorpe, Southwell, Middlesex.
 1887. †WARREN, Lieut.-General Sir CHARLES, R.E., K.C.B., G.C.M.G.,
 F.R.S., F.R.G.S. (Pres. E, 1887.) Athenæum Club, S.W.
 1875. *WATERHOUSE, Major-General J. Hurstmead, Eltham, Kent.
 1905. †Watermeyer, F. S., Government Land Surveyor, P.O. Box 973,
 Pretoria, South Africa.
 1904. †Waters, A. H., B.A. 48 Devonshire-road, Cambridge.
 1900. †Waterston, David, M.D., F.R.S.E. 23 Colinton-road, Edinburgh.
 1884. †Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
 1901. *WATSON, ARNOLD THOMAS, F.L.S. Southwold, Tapton Crescent-
 road, Sheffield.
 1886. *Watson, C. J. Alton Cottage, Botteville-road, Acock's Green,
 Birmingham.
 1906. §Watson, D. M. S. 466 Moss-lane East, Manchester.
 1892. §Watson, G., Assoc.M.Inst.C.E. Stonegate, Pool, near Leeds.
 1885. †Watson, Deputy Surgeon-General G.A. Hendre, Overton Park,
 Cheltenham.
 1906. *Watson, Henry Angus. 3 Museum-street, York.
 1889. †Watson, John, F.I.C. P.O. Box 1026, Johannesburg, South
 Africa.
 1905. †Watson, Dr. R. W. Ladysmith, Cape Colony.
 1894. *WATSON, Professor W., D.Sc., F.R.S. 7 Upper Cheyne-row, S.W.
 1892. §Watson, William, M.D. The Lea, Corstorphine, Midlothian.
 1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. The Crofts, Seascale,
 Cumberland.
 1901. §Watt, Henry Anderson. Ardenslate House, Hunter's Quay, Argyll-
 shire.
 1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
 1884. *Watts, Rev. Canon Robert R. The Red House, Bemerton, Salis-
 bury.
 1873. *WATTS, W. MARSHALL, D.Sc. Shirley, Vennor-road, Sydenham,
 S.E.
 1883. *WATTS, W. W., M.A., M.Sc., F.R.S., Sec.G.S. (Pres. C, 1903 ;
 Council, 1902-), Professor of Geology in the Royal College
 of Science, London, S.W.
 1870. §Watts, William, F.G.S. Little Don Waterworks, Langsett, near
 Penistone.
 1905. †Way, E. J. Post Office, Benoni, Transvaal.
 1905. §Way, W. A., M.A. The College, Graaf Reinet, South Africa.
 1905. †Webb, Miss Dora. Gezina School, Pretoria.
 1891. §Webber, Thomas. 12 Southey-terrace, Wordsworth-avenue, Roath,
 Cardiff.
 1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe.
 Jahnstrasse 5, Karlsruhe.
 1903. †Weekes, R. W., A.M.Inst.C.E. 65 Hayes-road, Bromley, Kent.
 1890. *WEISS, F. ERNEST, D.Sc., F.L.S., Professor of Botany in the
 Victoria University, Manchester.
 1905. †Welby, Miss F. A. Hamilton House, Hall-road, N.W.
 1902. †Welch, R. J. 49 Lonsdale-street, Belfast.
 1894. †Weld, Miss. 119 Iffley-road, Oxford.
 1880. *Weldon, Mrs. Merton Lea, Oxford.
 1881. §Wellcome, Henry S. Snow Hill-buildings, E.C.
 1881. †Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
 1881. *WENLOCK, The Right Hon. Lord, G.C.S.I., G.C.I.E., K.C.B., LL.D.
 Eserick Park, Yorkshire.

Year of
Election.

- Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Roslyn, Walland's Park, Lewes.
1886. *Wertheimer, Julius, B.A., B.Sc., F.C.S., Principal of and Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1900. §WEST, WILLIAM, F.L.S. 26 Woodville-terrace, Horton-lane, Bradford.
1903. §Westaway, F. W. 1 Pemberley-crescent, Bedford.
1882. *Westlake, Ernest, F.G.S. Fordingbridge, Salisbury.
1900. †Wethey, E. R., M.A., F.R.G.S. 4 Cunliffe-villas, Manningham, Bradford.
1904. §Weymouth, E. S., M.A. 27 Southampton-street, Strand, W.C.
1878. *Wheeler, W. H., M.Inst.C.E. Wyncote, Boston, Lincolnshire.
1888. §Whelen, John Leman. 18 Frognal, Hampstead, N.W.
1893. *WHETHAM, W. C. D., M.A., F.R.S. Upwater Lodge, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1879. *WHIDBORNE, REV. GEORGE FERRIS, M.A., F.G.S. Hammerwood, Lodge, East Grinstead, Sussex.
1898. *Whipple, Robert S. Scientific Instrument Company, Cambridge.
1883. *Whitaker, T. Walton House, Burley-in-Wharfedale.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. (Pres. C, 1895 ; Council, 1890-96.) 3 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, A. SILVA. (ASSISTANT-SECRETARY.) Burlington House, W.
1904. †White, H. Lawrence, B.A. 2 St. Margaret's-terrace, Cheltenham.
1885. *White, J. Martin. Balruddery, Dundee.
1905. †White, Miss J. R. Huguenot College, Wellington, Cape Colony.
1897. *WHITE, Sir W. H., K.C.B., F.R.S. (Pres. G, 1899 ; Council, 1897-1900.) Cedarcroft, Putney Heath, S.W.
1877. *White, William. 20 Hillersdon-avenue, Church-road, Barnes, S.W.
1904. †WHITEHEAD, J. E. L., M.A. (Local Sec. 1904.) Guildhall, Cambridge.
1883. †Whitehead, P. J. 6 Cross-street, Southport.
1905. §Whiteley, Miss M. A., D.Sc. Royal College of Science, S.W.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 5 Bagnall-street, West Bromwich.
1905. *Whitmee, Harold Babington. Care of India Rubber Co., Ltd., 213 West-street, Durban, Natal.
1891. §Whitmell, Charles T., M.A., B.Sc. Invermay, Hyde Park, Leeds.
1896. §Whitney, Colonel C. A. 28 Croxteth-road, Liverpool.
1897. †WHITTAKER, E. T., M.A., F.R.S. Royal Astronomer of Ireland and Andrews' Professor of Astronomy in the University of Dublin. The Observatory, Dunsink, Co. Dublin.
1901. †Whitton, James. City-chambers, Glasgow.
1857. *WHITTY, REV. JOHN IRWINE, M.A., D.C.L., LL.D. Alpha-villa, Southwood, Ramsgate.
1905. †Whyte, B. M. Simon's Town, Cape Colony.
1905. §Wibberley, C. Beira and Mashonaland Railways, Umtali, South Africa.
1878. †Wigham, John R. Albany House, Mankstown, Dublin.
1889. *WILBERFORCE, L. R., M.A., Professor of Physics in the University of Liverpool.

Year of
Election.

1887. *WILDE, HENRY, D.Sc., D.C.L., F.R.S. The Hurst, Alderley Edge, Cheshire.
1905. †Wiley, J. R. Kingsfold, Mill-street, Cape Town.
1905. §Wilkins, R. F. Thatched House Club, St. James's-street, S.W.
1904. §Wilkinson, Hon. Mrs. Dringhouses Manor, York.
1900. †Wilkinson, J. B. Holme-lane, Dudley Hill, Bradford.
1903. †Willett, John E. 3 Park-road, Southport.
1904. *Williams, Miss Antonia. 6 Sloane-gardens, S.W.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, W.
1905. §Williams, Gardner F. 2201 R-street, Washington, D.C., U.S.A.
1883. †Williams, Rev. H. Alban, M.A. Sheering Rectory, Harlow, Essex.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1891. §Williams, J. A. B., M.Inst.C.E. Bloomfield, Caterham Valley, Surrey.
1883. *Williams, Mrs. J. Davies. 5 Chepstow-mansions, Bayswater, W.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke-vale, Clifton, Bristol.
1901. *Williams, Miss Mary. 6 Sloane-gardens, S.W.
1891. †Williams, Morgan. 5 Park-place, Cardiff.
1883. †Williams, T. H. 27 Water-street, Liverpool.
1877. *WILLIAMS, W. CARLETON, F.C.S. Broomgrove, Goring-on-Thames.
1906. §Williams, W. F. Lobb. 32 Lowndes-street, S.W.
1857. †WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1894. *Williamson, Mrs. Janora. Ardoyne, Birkbeck-road, Muswell Hill, N.
1895. †WILINK, W. (Local Sec. 1896.) 14 Castle-street, Liverpool.
1895. †Willis, John C., M.A., F.L.S., Director of the Royal Botanical Gardens, Peradeniya, Ceylon.
1896. †WILLISON, J. S. (Local Sec. 1897.) Toronto, Canada.
1859. *Wills, The Hon. Sir Alfred. Saxholm, Basset, Southampton.
1899. §Willson, George. Ivanhoe, Combermere-road, St. Leonards-on-Sea.
1899. §Willson, Mrs. George. Ivanhoe, Combermere-road, St. Leonards-on-Sea.
1901. †Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
1905. §Wilson, A. W. P.O. Box 24, Langlaagte, South Africa.
1886. †Wilson, Alexander B. Holywood, Belfast.
1878. †Wilson, Professor Alexander S., M.A., B.Sc. United Free Church Manse, North Queensferry.
1903. †Wilson, C. T. R., M.A., F.R.S. Sidney Sussex College, Cambridge.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Old Queen-street, Westminster, S.W.
1904. §Wilson, Charles John. Deanfield, Hawick, Scotland.
1904. §Wilson, David, M.D. Grove House, Paddock, Huddersfield.
1900. *Wilson, Duncan R. Menethorpe, Malton.
1847. *Wilson, F. Linford. 99 Albany-street, N.W.
1903. †Wilson, George. The University, Leeds.
1895. †Wilson, Dr. Gregg. Queen's College, Belfast.
1901. †Wilson, Harold A., M.A., D.Sc., F.R.S., Professor of Physics in King's College, London. 3 & 4 Clement's Inn, Strand, W.C.
1902. *Wilson, Harry, F.I.C. 32 Westwood-road, Southampton.
1883. *Wilson, Henry, M.A. Farnborough Lodge, Farnborough, R.S.O., Kent.

Year of
Election.

1879. †Wilson, Henry J. 255 Pitsmore-road, Sheffield.
 1885. †Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
 1905. †Wilson, J. F. H.M. Dockyard Extension, Simon's Town, Cape Colony.
 1865. †WILSON, Ven. Archdeacon JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
 1884. †Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
 1879. †Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
 1901. *Wilson, Joseph. Hillside House, Avon-road, Walthamstow, N.E.
 1901. †Wilson, Mrs. Mary R., M.D. *Ithaca, New York, U.S.A.*
 1905. †Wilson, Dr. R. Arderne. Saasveld House, Kloof-street, Cape Town.
 1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
 1883. †Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
 1892. §Wilson, T. Stacey, M.D. 27 Wheeley's-road, Edgbaston, Birmingham.
 1887. §Wilson, W., jun. Hillocks of Terpersie, by Alford, Aberdeenshire.
 1871. *WILSON, WILLIAM E., D.Sc., F.R.S. Daramona House, Streete, Rathowen, Ireland.
 1886. †WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., F.R.S., President of Queen's College, Cork.
 1863. *WINWOOD, Rev. H. H., M.A., F.G.S. (Local Sec. 1864.) 11 Cavendish-crescent, Bath.
 1905. §Wiseman, J. G., F.R.C.S., F.R.G.S. Stranraer, St. Peter's-road, St. Margaret's-on-Thames.
 1875. †WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1898 ; Council, 1899-1903.) 21 Delahay-street, Westminster, S.W.
 1905. †Wood, A., jun. Emmanuel College, Cambridge.
 1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
 1901. *Wood, Miss Ethel M. R. 59 Calthorpe-road, Edgbaston, Birmingham.
 1875. *Wood, George William Rayner. Summerville, Victoria Park, Manchester.
 1878. †WOOD, Sir H. TRUEMAN, M.A. Society of Arts, John-street, Adelphi, W.C. ; and 16 Leinster-square, Bayswater, W.
 1883. *Wood, J. H. 21 Westbourne-road, Birkdale, Lancashire.
 1904. §Wood, T. B., M.A. Caius College, Cambridge.
 1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.
 1901. *Wood, William James. 266 George-street, Glasgow.
 1899. *Woodcock, Mrs. E. M. Pahargoomiah Tea Association, Bagdoora P.O., via Sillguri, North Bengal, India.
 1896. *WOODHEAD, Professor G. SIMS, M.D. Pathological Laboratory, Cambridge.
 1888. *Woodiwiss, Mrs. Alfred. 121 Castlenau, Barnes, S.W.
 1906. §Woodland, W. N. F. King's College, W.C.
 1904. §Woodrow, John. Berryknowe, Meikleriggs, Paisley.
 1904. †Woods, Henry, M.A. St. John's College, Cambridge.
 WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, E.C.
 1887. *WOODWARD, ARTHUR SMITH, LL.D., F.R.S., F.L.S., F.G.S. (Council, 1903-), Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
 1869. *WOODWARD, C. J., B.Sc., F.G.S. 127 Metchley-lane, Harborne, Birmingham.
 1886. †Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
 1866. †WOODWARD, HENRY, LL.D., F.R.S., F.G.S. (Pres. C, 1887 ; Council, 1887-94.) 129 Beaufort-street, Chelsea, S.W.

- Year of Election.
1870. †WOODWARD, HORACE B., F.R.S., F.G.S. Geological Survey Office, Jermyn-street, S.W.
1894. *Woodward, John Harold. 8 Queen Anne's gate, Westminster, S.W.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1890. *Woolcombe, 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.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1901. †Worth, J. T. Oakenrod Mount, Rochdale.
1904. §WORTHINGTON, A. M., C.B., F.R.S., Professor of Physics in the Royal Naval Engineering College, Devonport. Mohuns, Tavistock.
1855. *Worthington, Rev. Alfred William, B.A. Old Swinford, Stourbridge.
1906. §WRAGGE, R. H. VERNON. York.
1896. †Wrench, Edward M., F.R.C.S. Park Lodge, Baslow, Derbyshire.
1905. †Wrentmore, G. G. Marva, Silwood-road, Rondebosch, Cape Colony.
1906. §Wright, Sir A. E. 7 Lower Seymour-street, W.
1905. †Wright, Allan. Struan Villa, Gardens, Cape Town.
1883. *Wright, Rev. Arthur, D.D. Queens' College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1905. *Wright, FitzHerbert. The Hayes, Alfreton.
1874. †Wright, Joseph, F.G.S. 4 Alfred-street, Belfast.
1884. †WRIGHT, Professor R. RAMSAY, M.A., B.Sc. University College, Toronto, Canada.
1904. †Wright, R. T. Goldieslie, Trumpington, Cambridge.
1903. †Wright, William. The University, Birmingham.
1871. †WRIGHTSON, Sir THOMAS, Bart., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1902. †Wyatt, G. H. 1 Maurice-road, St. Andrew's Park, Bristol.
1901. †Wylie, Alexander. Kirkfield, Johnstone, N.B.
1902. †Wylie, John. 2 Mafeking-villas, Whitehead, Belfast.
1899. †WYNNE, W. P., D.Sc., F.R.S., Professor of Chemistry in the University of Sheffield. 106 Whitham-road, Sheffield.
1905. †Yallop, J. Allan. Alandale, London-road, Sea Point, Cape Colony.
1901. *Yapp, R. H., M.A., Professor of Botany in University College, Aberystwyth.
- . *Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Poplar, E.
1905. §Yerbury, Colonel. Army and Navy Club, Pall Mall, S.W.
1886. *YOUNG, A. H., M.B., F.R.C.S. (Local Sec. 1887), Professor of Anatomy in the Victoria University, Manchester.
1904. †Young, Alfred. Selwyn College, Cambridge.
1891. §Young, Alfred C., F.C.S. 17 Vicar's-hill, Lewisham, S.E.
1905. §Young, Professor Andrew, M.A., B.Sc. South African College, Cape Town.
1894. *Young, George, Ph.D. Lauraville, Bradda, Port Erin, Isle of Man.
1876. *Young, John. 2 Montague-terrace, Kelvinside, Glasgow.
1905. †Young, Professor R. B. Transvaal Technical Institute, Johannesburg.
1885. †Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.
1901. †Young, Robert M., B.A. Rathvarna, Belfast.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S. (Pres. B, 1904), Professor of Chemistry in the University of Dublin. 12 Raglan-road, Dublin.
1887. †Young, Sydney. 29 Mark-lane, E.C.
1903. §Yoxall, J. H., M.P. 67 Russell-square, W.C.

CORRESPONDING MEMBERS.

- Year of
Election.
1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, D.C., U.S.A.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18.)
1881. Professor G. F. Barker. 3909 Locust-street, Philadelphia, U.S.A.
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, Liège, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 11, 4, Germany.
1892. Professor M. Bertrand. 75 rue de Vaugirard, Paris.
1894. Deputy Surgeon-General J. S. Billings. 40 Lafayette-place, New York, U.S.A.
1893. Professor Christian Bohr. Bredgade 62, Copenhagen, Denmark.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, U.S.A.
1884. Professor H. P. Bowditch, M.D., LL.D. Harvard Medical School, Boston, Massachusetts, U.S.A.
1890. Professor Dr. L. Brentano. Friedrichstrasse 11, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Christiania, Norway.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale University, New Haven, Conn., U.S.A.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, U.S.A.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. 65 Via Zamboni, Bologna, Italy.
1887. Hofrath Dr. H. Caro. C. 8, No. 9, Mannheim, Germany.
1894. Emile Cartailhac. 5 rue de la Chainé, Toulouse, France.
1861. Professor Dr. J. Victor Carus. Universitätstrasse 15, Leipzig.
1901. Professor T. C. Chamberlin. Chicago, U.S.A.
1894. Dr. A. Chauveau. 7 rue Cuvier, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, D.C., U.S.A.
1873. Professor Guido Cora. Via Goito 2, Rome.
1889. W. H. Dall. United States Geological Survey, Washington, D.C., U.S.A.
1901. Dr. Yves Delage. Paris.
1872. Professor G. Dewalque. 17 rue de la Paix, Liège, Belgium.
1870. Dr. Anton Dohrn, D.C.L. Naples.
1890. Professor V. Dwelshauvers-Dery. 4 quai Marcellis, Liège, Belgium.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
1901. Professor H. Elster. Wolfenbüttel, Germany.

Year of
Election.

1894. Professor T. W. W. Engelmann, D.C.L. Neue Wilhelmstrasse 15, Berlin, N.W.
1901. Professor W. G. Farlow. Harvard, U.S.A.
1874. Dr. W. Feddersen. Carolinenstrasse 9, Leipzig.
1886. Dr. Otto Finsch. Altewiekring, No. 19b, Braunschweig, Germany.
1887. Professor Dr. R. Fittig. Strassburg.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W. 48.
1872. W. de Fonvielle. 50 rue des Abbesses, Paris.
1901. Professor A. P. N. Franchimont. Leiden, Netherlands.
1894. Professor Léon Fredericq. 20 rue de Pitteurs, Liège, Belgium.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague, Bohemia.
1892. Professor Dr. Gustav Fritsch. Dorotheenstrasse 35, Berlin.
1881. Professor C. M. Gariel. 6 rue Edouard Détaillé, Paris.
1866. Dr. Gaudry. 7 bis rue des Saints Pères, Paris.
1901. Professor Dr. H. Geitel. Wolfenbüttel, Germany.
1884. Professor Wolcott Gibbs. Newport, Rhode Island, U.S.A.
1892. Daniel C. Gilman. Johns Hopkins University, Baltimore, U.S.A.
1889. Professor Gustave Gilson. l'Université, Louvain, Belgium.
1889. A. Gobert, 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 37 Gorham-street, Cambridge, Mass, U.S.A.
1895. Professor Dr. Emil Chr. Hansen. Carlsberg Laboratorium, Copenhagen, Denmark.
1893. Professor Paul Heger. 23 rue de Drapiers, Brussels.
1894. Professor Ludimar Hermann. Universität, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoologisches Institut, Alte Akademie, Munich.
1893. Professor Hildebrand. Stockholm.
1897. Dr. G. W. Hill. West Nyack, New York, U.S.A.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. The University, Utrecht, Netherlands.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, R.I., 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 Polar, Massagno, Lugano, 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. 153 rue de Fragnée, Liège.
1876. Dr. Giuseppe Jung. Bastions Vittoria 41, Milan.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tokyo, Japan.
1873. Professor Dr. Felix Klein. Wilhelm-Weberstrasse 3, Göttingen.
1894. Professor Dr. L. Kny. Kaiser-Allee 186-7, Wilmersdorf, bei Berlin.
1896. Professor F. Kohlrausch. Marburg, Germany.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1894. Maxime Kovalevsky. 13 Avenue de l'Observatoire, Paris, France.
1887. Professor W. Krause. Knesebeckstrasse, 17/1, Charlottenburg, bei Berlin.
1877. Dr. Hugo Kronecker, Professor of Physiology. Universität, Bern, Switzerland.
1887. Professor A. Ladenburg. Kaiser Wilhelmstrasse 108, Breslau.
1887. Professor J. W. Langley. 2037 Geddes-avenue, Ann Arbor, Michigan, U.S.A.

Year of
Election.

1872. M. Georges Lemoine. 76 rue Notre Dame des Changes, Paris.
 1901. Professor Philipp Lenard. Kiel.
 1887. Professor A. Lieben. IX. Wasagasse 9, Vienna.
 1883. Dr. F. Lindemann. Franz-Josefstrasse 12/I, Munich.
 1877. Dr. M. Lindemann. Sennorrstrasse 62, II, Dresden.
 1887. Professor Dr. Georg Lunge. Rämistrasse 56, Zurich, V.
 1871. Professor Jacob Lüroth. Mozartstrasse 10, and Universität,
 Freiburg-in-Breisgau, Germany.
 1894. Professor Dr. Otto Maas. Universität, Munich.
 1887. Henry C. McCook, D.D., Sc.D., LL.D. 3700 Chestnut-street,
 Philadelphia, U.S.A.
 1867. Professor Mannheim. 1 Boulevard Beauséjour, Paris.
 1887. Dr. C. A. von 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. Université, St. Petersburg.
 1887. Professor N. Menschutkin. St. Petersburg.
 1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
 1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, U.S.A.
 1894. Professor G. Mittag-Leffler. Djursholm. Stockholm.
 1893. Professor H. Moissan. The Sorbonne, Paris (7 rue Vauquelin).
 1894. Dr. Edmund von Mojsisovics. Strohgasse 26, Vienna, III/3.
 1897. Professor Oskar Montelius. St. Paulsgatan 11, Stockholm, Sweden.
 1897. Professor E. W. Morley, LL.D. West Hartford, Connecticut,
 U.S.A.
 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.
 1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
 1894. Baron Osten-Sacken. Heidelberg.
 1890. Professor W. Ostwald. Linnéstrasse 2, Leipzig.
 1890. Maffeo Pantaleoni. 13 Cola di Rienzo, Rome.
 1895. Professor F. Paschen. Universität, Tübingen.
 1887. Dr. Pauli. Feldbergstrasse 49, Frankfurt a/Main, Germany.
 1901. Hofrath Professor A. Penck. Georgenstrasse 34-36, Berlin, N.W. 7.
 1890. Professor Otto Pettersson. Stockholms Hogskola, Stockholm.
 1894. Professor W. Pfeffer, D.C.L. Linnéstrasse 11, Leipzig.
 1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand, Belgium.
 1886. Professor F. W. Putnam. Harvard University, Cambridge, Massa-
 chusetts, U.S.A.
 1887. Professor Georg Quincke. Hauptstrasse 47, Friederichsbau, Heidel-
 berg.
 1868. L. Radlkofer, Professor of Botany in the University of Munich.
 Sonnenstrasse 7.
 1895. Professor Ira Remsen. Johns Hopkins University, Baltimore,
 U.S.A.
 1897. Professor Dr. C. Richet. 15 rue de l'Université, Paris, France.
 1896. Dr. van Rijckevorsel. Parklaan 3, Rotterdam, Netherlands.
 1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
 1890. A. Lawrence Rotch. Blue Hill Observatory, Readville, Massa-
 chusetts, U.S.A.
 1895. Professor Karl Runge. Goldgraben 20, Göttingen, Germany.

Year of
Election.

1901. Gen.-Major Rykatchew. Central Physical Observatory, St. Petersburg.
1894. Professor P. H. Schoute. The University, Groningen, Netherlands.
1874. Dr. G. Schweinfurth. Potsdamerstrasse 75A, Berlin.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1892. Dr. Maurits Snellen. Apeldoorn, Pays-Bas, Holland.
1887. Professor H. Graf Solms. Botanischer Garten, Strassburg.
1887. Ernest Solvay. 25 rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. 312 East 2nd-street, Cincinnati, Ohio, U.S.A.
1889. Professor G. Stefanescu. Strada Verde 8, Bucharest, Roumania.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1894. Professor E. Strasburger. The University, Bonn.
1881. Professor Dr. Rudolf Sturm. Fränkelplatz 9, Breslau.
1887. Dr. T. M. Treub. Buitenzorg, Java.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, U.S.A.
- Arminius Vambéry, 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. 21 rue Belliard, Brussels, Belgium.
1887. Professor H. F. Weber. Zurich.
1887. Professor Dr. Leonhard Weber. Moltkestrasse 60, Kiel.
1887. Professor August Weismann. Freiburg-in-Breisgau, Baden.
1887. Dr. H. C. White. Athens, Georgia, U.S.A.
1881. Professor H. M. Whitney. Branford, Conn., U.S.A.
1887. Professor E. Wiedemann. Erlangen.
1887. Professor Dr. R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.
1887. Dr. Otto N. Witt. Ebereschen-Allée 10, Westend bei Berlin, N.W. 23.
1876. Professor Adolph Wüllner. Aureliusstrasse 9, Aachen.
1887. Professor C. A. Young. Hanover, New Hampshire, U.S.A.
1896. Professor E. Zacharias. Botanischer Garten, Hamburg.
1887. Professor F. Zirkel. Thalstrasse 33, Leipzig.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND.

- Belfast, Queen's College.
 Birmingham, Midland Institute.
 Bradford Philosophical Society.
 Brighton Public Library.
 Bristol Naturalists' Society.
 —, The Museum.
 Cambridge Philosophical Society.
 Cardiff, University College.
 Chatham, Royal Engineers' Institute.
 Cornwall, Royal Geological Society of.
 Dublin, Geological Survey of Ireland.
 —, Royal College of Surgeons in Ireland.
 —, Royal Geological Society of Ireland.
 —, Royal Irish Academy.
 —, Royal Society of.
 Dundee, University College.
 Edinburgh, Royal Society of.
 —, Royal Medical Society of.
 —, Scottish Society of Arts.
 Exeter, Albert Memorial Museum.
 Glasgow Philosophical Society.
 —, Institution of Engineers and Shipbuilders in Scotland.
 Leeds, Institute of Science.
 —, Philosophical and Literary Society of.
 Liverpool, Free Public Library.
 —, Royal Institution.
 —, The University.
 London, Admiralty, Library of the.
 —, Anthropological Institute.
 —, Arts, Society of.
 —, Chemical Society.
 —, Civil Engineers, Institution of.
 —, Geological Society.
 —, Geology, Museum of Practical, 28 Jermyn Street.
 —, Greenwich, Royal Observatory.
 —, Guildhall, Library,
 —, King's College.
 —, Linnean Society.
 London, London Institution.
 —, Mechanical Engineers, Institution of.
 —, Meteorological Office.
 —, Physical Society.
 —, Royal Asiatic Society.
 —, Royal Astronomical Society.
 —, Royal College of Physicians.
 —, Royal College of Surgeons.
 —, Royal Geographical Society.
 —, Royal Institution.
 —, Royal Meteorological Society.
 —, Royal Society.
 —, Royal Statistical Society.
 —, Sanitary Institute.
 —, United Service Institution.
 —, University College.
 —, War Office, Library.
 —, Zoological Society.
 Manchester Literary and Philosophical Society.
 —, Municipal School of Technology.
 Newcastle-upon-Tyne, Literary and Philosophical Society.
 —, Public Library.
 Norwich, The Free Library.
 Nottingham, The Free Library.
 Oxford, Ashmolean Natural History Society.
 —, Radcliffe Observatory.
 Plymouth Institution.
 —, Marine Biological Association.
 Salford, Royal Museum and Library.
 Sheffield, University College.
 Southampton, Hartley Institution.
 Stonyhurst College Observatory.
 Surrey, Royal Gardens, Kew.
 —, National Physical Laboratory (Observatory Department).
 Swansea, Royal Institution of South Wales.
 Yorkshire Philosophical Society.
 The Corresponding Societies.

EUROPE.

Berlin	Die Kaiserliche Akademie der Wissenschaften.	Modena	Royal Academy.
Bonn	University Library.	Moscow	Society of Naturalists.
Brussels	Royal Academy of Sciences.	—	University Library.
Charkow	University Library.	Munich.....	University Library.
Coimbra	Meteorological Observatory.	Naples	Royal Academy of Sciences.
Copenhagen...	Royal Society of Sciences.	Paris.....	Association Française pour l'Avancement des Sciences.
Dorpat, Russia	University Library.	—	Geographical Society.
Dresden	Royal Public Library.	—	Geological Society.
Frankfort ...	Natural History Society.	—	Royal Academy of Sciences.
Geneva.....	Natural History Society.	—	School of Mines.
Göttingen	University Library.	Pultova	Imperial Observatory.
Grätz	Naturwissenschaftlicher Verein.	Rome	Accademia dei Lincei.
Halle	Leopoldinisch - Carolinische Akademie.	—	Collegio Romano.
Harlem	Société Hollandaise des Sciences.	—	Italian Geographical Society.
Heidelberg...	University Library.	—	Italian Society of Sciences.
Helsingfors ...	University Library.	Roumania ..	Roumanian Association for the Advancement of Science.
Jena	University Library.	St. Petersburg.	University Library.
Kazan, Russia	University Library.	—	Imperial Observatory.
Kiel	Royal Observatory.	Stockholm ...	Royal Academy.
Kiev	University Library.	Turin	Royal Academy of Sciences.
Lausanne	The University.	Upsala	Royal Society of Science.
Leyden.....	University Library.	Utrecht	University Library.
Liège	University Library.	Vienna	The Imperial Library.
Lisbon	Academia Real des Sciences.	—	Central Anstalt für Meteorologie und Erdmagnetismus.
Milan	The Institute.		

ASIA.

Agra	The College.	Calcutta	Medical College.
Bombay	Elphinstone Institution.	—	Presidency College.
—	Grant Medical College.	Ceylon	The Museum, Colombo.
Calcutta	Asiatic Society.	Madras	The Observatory.
—	Hooghly College.	—	University Library.
		Tokyo	Imperial University.

AFRICA.

Cape Town	The Royal Observatory.
—	South African Association for the Advancement of Science.
—	South African Public Library.
Kimberley	Public Library.

AMERICA.

Albany	The Institute.	Montreal	Council of Arts and Manufactures.
Amherst.....	The Observatory.	—	McGill University.
Baltimore	Johns Hopkins Uni- versity.	New York ...	American Society of Civil Engineers.
Boston	American Academy of Arts and Sciences.	—	Lyceum of Natural History.
—	Boston Society of Natural History.	Ottawa.....	Geological Survey of Canada.
California.....	The University.	Philadelphia ..	American Philosophi- cal Society.
—	Lick Observatory.	—	Franklin Institute.
—	Academy of Sciences.	—	University of Penn- sylvania.
Cambridge ...	Harvard University Library.	Toronto	The Observatory.
Chicago	American Medical Association.	—	The Canadian Insti- tute.
—	Field Museum of Natural History.	—	The University.
Kingston	Queen's University.	Washington... Bureau of Ethnology.	
Manitoba ...	Historical and Scien- tific Society	—	Smithsonian Institu- tion.
—	The University.	—	The Naval Observa- tory.
Massachusetts	Marine Biological Laboratory, Woods Holl.	—	United States Geol- ogical Survey of the Territories.
Mexico	Sociedad Cientifica 'Antonio Alzate.'	—	Library of Congress.
Missouri	Botanical Garden.	—	Board of Agriculture.

AUSTRALIA.

Adelaide	The Colonial Government.
—	The Royal Geographical Society.
Brisbane	Queensland Museum.
Melbourne	Public Library.
Sydney	Public Works Department.
—	Australian Museum.
Tasmania	Royal Society.
Victoria.....	The Colonial Government.

NEW ZEALAND.

Canterbury	The Museum
Wellington	New Zealand Institute.

20 APR. 1907





