REPORT

OF THE

SEVENTY-EIGHTH MEETING OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

DUBLIN

SEPTEMBER 1908

LONDON
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1909

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PATRON.

HIS MAJESTY THE KING.

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HIS EXCELLENCY THE GOVERNOR-GENERAL OF THE DOMINION OF CANADA.

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H. C. STEWARDSON, Burlington House, London, W.

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JOHN AIRD.

LOCAL SECRETARIES FOR THE MEETING AT WINNIPEG.

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W. SANFORD EVANS.
Professor M. A. PARKER, B.Sc.
Professor SWALE VINCENT, M.D.

[P.T.O.

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AUDITORS.

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

RULES OF THE BRITISH ASSOCIATION.

[*Adopted by the General Committee at Leicester*, 1907.]

Chapter I.

Objects and Constitution.

1. The objects of the British Association for the Advancement of Science 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 more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress. Objects.

The Association contemplates no invasion of the ground occupied by other Institutions.

2. The Association shall consist of Members, Associates, and Honorary Corresponding Members. Constitution.

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee.

3. The Association shall meet annually, for one week or longer, and at such other times as the General Committee may appoint. The place of each Annual Meeting shall be determined by the General Committee not less than two years in advance; and the arrangements for these meetings shall be entrusted to the Officers of the Association. Annual Meetings.

Chapter II.

The General Committee.

1. The General Committee shall be constituted of the following persons: Constitution.

(i) *Permanent Members*—

(*a*) Past and present Members of the Council, and past and present Presidents of the Sections.

(b) Members who, by the publication of works or papers, have furthered the advancement of knowledge in any of those departments which are assigned to the Sections of the Association.

(ii) *Temporary Members*—

(a) Vice-Presidents and Secretaries of the Sections.
(b) Honorary Corresponding Members, foreign representatives, and other persons specially invited or nominated by the Council or General Officers.
(c) Delegates nominated by the Affiliated Societies.
(d) Delegates—not exceeding altogether three in number—from Scientific Institutions established at the place of meeting.

Admission. 2. The decision of the Council on the qualifications and claims of any Member of the Association to be placed on the General Committee shall be final.

(i) Claims for admission as a Permanent Member must be lodged with the Assistant Secretary at least one month before the Annual Meeting.
(ii) Claims for admission as a Temporary Member may be sent to the Assistant Secretary at any time before or during the Annual Meeting.

Meetings. 3. The General Committee shall meet twice at least during every Annual Meeting. In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee.

Functions. 4. The General Committee shall

(i) Receive and consider the report of the Council.
(ii) Elect a Committee of Recommendations.
(iii) Receive and consider the report of the Committee of Recommendations.
(iv) Determine the place of the Annual Meeting not less than two years in advance.
(v) Determine the date of the next Annual Meeting.
(vi) Elect the President and Vice-Presidents, Local Treasurer and Local Secretaries for the next Annual Meeting.
(vii) Elect Ordinary Members of Council.
(viii) Appoint General Officers.
(ix) Appoint Auditors.
(x) Elect the officers of the Conference of Delegates.
(xi) Receive any notice of motion for the next Annual Meeting.

Chapter III.

Committee of Recommendations.

1. The *ex officio* Members of the Committee of Recommendations are the President and Vice-Presidents of the Association and the President of each Section at the Annual Meeting, the General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years Constitution.

An Ordinary Member of the Committee for each Section shall be nominated by the Committee of that Section.

If the President of a Section be unable to attend a meeting of the Committee of Recommendations, the Sectional Committee may appoint a Vice-President, or some other member of the Committee, to attend in his place, due notice of such appointment being sent to the Assistant Secretary.

2. Every recommendation made under Chapter IV. and every resolution on a scientific subject, which may be submitted to the Association by any Sectional Committee, or by the Conference of Delegates, or otherwise than by the Council of the Association, shall be submitted to the Committee of Recommendations. If the Committee of Recommendations approve such recommendation, they shall transmit it to the General Committee; and no recommendation shall be considered by the General Committee that is not so transmitted. Functions.

Every recommendation adopted by the General Committee shall, if it involve action on the part of the Association, be transmitted to the Council; and the Council shall take such action as may be needful to give effect to it, and shall report to the General Committee not later than the next Annual Meeting.

Every proposal for establishing a new Section or Sub-Section, for altering the title of a Section, or for any other change in the constitutional forms or fundamental rules of the Association, shall be referred to the Committee of Recommendations for their consideration and report.

3. The Committee of Recommendations shall assemble, for the despatch of business, on the Monday of the Annual Meeting, and, if necessary, on the following day. Their Report must be submitted to the General Committee on the last day of the Annual Meeting. Procedure.

Chapter IV.

Research Committees.

Procedure.

1. Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section; and, if such proposal be approved, it shall be referred to the Committee of Recommendations.

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee, composed of Members of the Association, to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association; and the Committee of Recommendations may include such recommendation in their report to the General Committee.

Constitution.

2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and suitable Members to serve on it, which must be as small as is consistent with its efficient working; and shall nominate a Chairman and a Secretary. Such Research Committee, if appointed, shall have power to add to their numbers.

Proposals by Sectional Committees.

3. The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required.

All proposals sanctioned by a Sectional Committee shall be forwarded by the Recorder to the Assistant Secretary not later than noon on the Monday of the Annual Meeting for presentation to the Committee of Recommendations.

Tenure.

4. Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment, with or without a grant—or a further grant—of money.

Reports.

5. Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed. Interim Reports, whether intended for publication or not, must be submitted in writing. Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee

appointed on their recommendation, and shall report to the Committee of Recommendations on or before the Monday of the Annual Meeting.

GRANTS. (*a*) Drawn by Chairman.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for such portion of the sum granted as from time to time may be required.

(*b*) Expire on June 30.

Grants of money sanctioned at the Annual Meeting expire on June 30 following. The General Treasurer is not authorised, after that date, to allow any claims on account of such grants.

(*c*) Accounts, and balance in hand.

The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then either return the balance of the grant, if any, which remains unexpended, or, if further expenditure be contemplated, apply for leave to retain the balance.

(*d*) Additional Grants.

When application is made for a Committee to be reappointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired.

(*e*) *Caveat.*

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

A Research Committee, whether or not in receipt of a grant, shall not raise money, in the name or under the auspices of the Association, without special permission from the General Committee.

Disposal of specimens, apparatus, &c.

7. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their Reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct.

Committees are required 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 is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

Chapter V.

The Council.

Constitution. 1. The Council shall consist of *ex officio* Members and of Ordinary Members elected annually by the General Committee.

(i) The *ex officio* Members are—the Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

(ii) The Ordinary Members shall not exceed twenty-five in number. Of these, not more than twenty shall have served on the Council as Ordinary Members in the previous year.

Functions. 2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee.

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt the Annual Report, and to consider other matters to be brought before the General Committee.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

Suggestions for the Presidency shall be considered by the Council at the Meeting in February, and the names selected shall be issued with the summonses to the Council Meeting in March, when the nomination shall be made from the names on the list.

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

3. Election to the Council shall take place at the same time as that of the Officers of the Association. Elections.

(i) At each Annual Election, the following Ordinary Members of the Council shall be ineligible for re-election in the ensuing year:

(*a*) Three of the Members who have served for the longest consecutive period, and

(*b*) Two of the Members who, being resident in or near London, have attended the least number of meetings during the past year.

Nevertheless, it shall be competent for the Council, by an unanimous vote, to reverse the proportion in the order of retirement above set forth.

(ii) The Council shall submit to the General Committee, in their Annual Report, the names of twenty-three Members of the Association whom they recommend for election as Members of Council.

(iii) Two Members shall be elected by the General Committee, without nomination by the Council; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place.

Any member of the General Committee may propose another member thereof for election as one of these two members of Council, and, if only two are so proposed, they shall be declared elected; but, if more than two are so proposed, the election shall be by show of hands, unless five members at least require it to be by ballot.

Chapter VI.

The President, General Officers, and Staff.

1. The President assumes office on the first day of the Annual Meeting, when he delivers a Presidential Address. He resigns office at the next Annual Meeting, when he inducts his successor into the Chair. The President.

The President shall preside at all meetings of the Association or of its Council and Committees which he attends in his capacity as President. In his absence, he shall be represented by a Vice-President or past President of the Association.

2. The General Officers of the Association are the General Treasurer and the General Secretaries. General Officers.

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

The General Treasurer.

3. The General Treasurer shall be responsible to the General Committee and the Council for the financial affairs of the Association.

The General Secretaries.

4. The General Secretaries shall control the general organisation and administration, and shall be responsible to the General Committee and the Council for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance.

The Assistant Secretary.

5. The Assistant Secretary shall hold office during the pleasure of the Council. He shall act under the direction of the General Secretaries, and in their absence shall represent them. He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relates to the finances of the Association.

The Assistant Secretary shall be charged, subject as aforesaid: (i) with the general organising and editorial work, and with the administrative business of the Association; (ii) with the control and direction of the Office and of all persons therein employed; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council. He shall act as Secretary, and take Minutes, at the meetings of the Council, and at all meetings of Committees of the Council, of the Committee of Recommendations, and of the General Committee.

Assistant Treasurer.

6. The General Treasurer may depute one of the Staff, as Assistant Treasurer, to carry on, under his direction, the routine work of the duties of his office.

The Assistant Treasurer shall be charged with the issue of Membership Tickets, the payment of Grants, and such other work as may be delegated to him.

CHAPTER VII.

Finance.

Financial Statements.

1. The General Treasurer, or Assistant Treasurer, shall receive and acknowledge all sums of money paid to the Association. He shall submit, at each meeting of the Council, an *interim* statement of his Account; and, after

June 30 in each year, he shall prepare and submit to the General Committee a balance-sheet of the Funds of the Association.

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

3. The General Treasurer shall make all ordinary payments authorised by the General Committee or by the Council. Expenditure.

4. The General Treasurer is empowered to draw on the account of the Association, and to invest on its behalf, part or all of the balance standing at any time to the credit of the Association in the books of the Bank of England, either in Exchequer Bills or in any other temporary investment, and to change, sell, or otherwise deal with such temporary investment as may seem to him desirable. Investments.

5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association. Cheques.

Chapter VIII.

The Annual Meetings.

1. Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number. Local Officers and Committees

2. The General Committee shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Assistant Secretary as to the local arrangements necessary for the conduct of the meeting. The Local Treasurers shall be empowered to enrol Members and Associates, and to receive subscriptions.

3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections. Functions.

Chapter IX.

The Work of the Sections.

The Sections.

1. The scientific work of the Association shall be transacted under such Sections as shall be constituted from time to time by the General Committee.

It shall be competent for any Section, if authorised by the Council for the time being, to form a Sub-Section for the purpose of dealing separately with any group of communications addressed to that Section.

Sectional Officers.

2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries. They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

Rooms.

3. The Section Rooms and the approaches thereto shall not be used for any notices, exhibitions, or other purposes than those of the Association.

Sectional Committees.

4. The work of each Section shall be conducted by a Sectional Committee, which shall consist of the following:—

Constitution.

(i) The Officers of the Section during their term of office.
(ii) All past Presidents of that Section.
(iii) Such other Members of the Association, present at any Annual Meeting, as the Sectional Committee, thus constituted, may co-opt for the period of the meeting:

Provided always that—

Privilege of Old Members.

(*a*) Any Member of the Association who has served on the Committee of any Section in any previous year, and who has intimated his intention of being present at the Annual Meeting, is eligible as a member of that Committee at their first meeting.

Daily Co-optation.

(*b*) A Sectional Committee may co-opt members, as above set forth, at any time during the Annual Meeting, and shall publish daily a revised list of the members.

(c) A Sectional Committee may, at any time during the Annual Meeting, appoint not more than three persons present at the meeting to be Vice-Presidents of the Section, in addition to those previously appointed by the Council. Additional Vice-Presidents.

5. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee; and they shall report such action to the Sectional Committee at its next meeting. EXECUTIVE FUNCTIONS

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise. Of President.

The Recorder shall be responsible for the punctual transmission to the Assistant Secretary of the daily programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee. And of Recorder.

6. The Sectional Committee shall nominate, before the close of the Annual Meeting, not more than six of its own members to be members of an Organising Committee, with the officers to be subsequently appointed by the Council, and past Presidents of the Section, from the close of the Annual Meeting until the conclusion of its meeting on the first day of the ensuing Annual Meeting. Organising Committee.

Each Organising Committee shall hold such Meetings as are deemed necessary by its President for the organisation of the ensuing Sectional proceedings, and shall hold a meeting on the first Wednesday of the Annual Meeting: to nominate members of the Sectional Committee, to confirm the Provisional Programme of the Section, and to report to the Sectional Committee.

Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting: to co-opt members, to complete the arrangements for the next day, and to take into consideration any suggestion for the advancement of Science that may be offered by a member, or may arise out of the proceedings of the Section. Sectional Committee.

No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes. Papers and Reports.

Any report or paper read in any one Section may be read also in any other Section.

No paper or abstract of a paper shall be printed in the Annual Report of the Association unless the manuscript has been received by the Recorder of the Section before the close of the Annual Meeting.

Recommendations.

It shall be within the competence of the Sectional Committee to review the recommendations adopted at preceding Annual Meetings, as published in the Annual Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed; and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required: to make recommendations and nominate individuals or Research Committees to whom the preparation of such reports, or the task of research, may be entrusted, discriminating as to whether, and in what respects, these objects may be usefully advanced by the appropriation of money from the funds of the Association, whether by reference to local authorities, public institutions, or Departments of His Majesty's Government. The appointment of such Research Committees shall be made in accordance with the provisions of Chapter IV.

No proposal arising out of the proceedings of any Section shall be referred to the Committee of Recommendations unless it shall have received the sanction of the Sectional Committee.

Publication.

7. Papers ordered to be printed *in extenso* shall not be included in the Annual Report, if published elsewhere prior to the issue of the Annual Report in volume form. Reports of Research Committees shall not be published elsewhere than in the Annual Report without the express sanction of the Council.

Copyright.

8. The copyright of papers ordered by the General Committee to be printed *in extenso* in the Annual Report shall be vested in the authors; and the copyright of the reports of Research Committees appointed by the General Committee shall be vested in the Association.

Chapter X.

Admission of Members and Associates.

Applications.

1. No technical qualification shall be required on the part of an applicant for admission as a Member or as an Associate of the British Association; but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect.

Obligations.

*Every person admitted as a Member or an Associate shall conform to the Rules and Regulations of the Association, any infringement of which on his part may render him liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued.

It shall be competent for the General Officers to act, in the name of the Council, on any occasion of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next Meeting.

Conditions and Privileges of Membership.

2. All Members are eligible to any office in the Association.

(i) Every *Life Member* shall pay, on admission, the sum of Ten Pounds.

Life Members shall receive *gratis* the Annual Reports of the Association.

(ii) Every *Annual Member* shall pay, on admission, the sum of Two Pounds, and in any subsequent year the sum of One Pound.

Annual Members shall receive *gratis* the Report of the Association for the year of their admission and for the years in which they continue to pay, *without intermission*, their annual subscription. An Annual Member who omits to subscribe for any particular year shall lose for that and all future years the privilege of receiving the Annual Reports of the Association *gratis*. He, however, may resume his other privileges as a Member at any subsequent Annual Meeting by paying on each such occasion the sum of One Pound.

(iii) Every *Associate* for a year shall pay, on admission, the sum of One Pound.

* Amended by the General Committee at Dublin, 1908.

Associates shall not receive the Annual Report gratuitously. They shall not be eligible to serve on any Committee, nor be qualified to hold any office in the Association.

(iv) *Ladies* may become Members or Associates on the same terms as gentlemen, or can obtain a *Lady's Ticket* (transferable to ladies only) on the payment of One Pound.

Corresponding Members

3. Corresponding Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership.

Annual Subscriptions.

4. Subscriptions are payable at or before the Annual Meeting. Annual Members not attending the meeting may make payment at any time before the close of the financial year on June 30 of the following year.

The Annual Report.

5. The Annual Report of the Association shall be forwarded *gratis* to individuals and institutions entitled to receive it.

Annual Members whose subscriptions have been intermitted shall be entitled to purchase the Annual Report at two-thirds of the publication price; and Associates for a year shall be entitled to purchase, at the same price, the volume for that year.

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

CHAPTER XI.

Corresponding Societies: Conference of Delegates.

Corresponding Societies are constituted as follows:

AFFILIATED SOCIETIES.

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

Each Affiliated Society may appoint a Delegate, who must be or become a Member of the Association and must attend the meetings of the Conference of Delegates. He shall be *ex officio* a Member of the General Committee.

ASSOCIATED SOCIETIES.

(ii) 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.

Each Associated Society shall have the right to appoint a Delegate to attend the Annual Conference. Such Delegates must be or become either Members or Associates of the British Association, and shall have all the rights of Delegates appointed by the Affiliated Societies, except that of membership of the General Committee.

Applications.

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

CORRESPONDING SOCIETIES COMMITTEE.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee, for the purpose of keeping themselves generally informed of the work of the Corresponding Societies and of superintending the preparation of a list of the papers published by the Affiliated Societies. This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable.

Procedure.

(i) Each Corresponding Society shall forward every year to the Assistant Secretary of the Association, on or before June 1, such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee.

(ii) There shall be inserted in the Annual Report of the Association a list of the papers published by the Corresponding Societies during the preceding twelve months which contain the results of 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 several Sections of the Association.

CONFERENCE OF DELEGATES.

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

Procedure and Functions.

(i) 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 discussions.

(ii) The Conference of Delegates shall be empowered to submit Resolutions to the Committee of Recommendations for their consideration, and for report to the General Committee.

(iii) The Sectional Committees of the Association shall be requested to transmit to the Secretaries of the Conference of Delegates copies of any recommendations to be made to the General Committee bearing on matters in which the co-operation of Corresponding Societies is desirable. It shall be competent for the Secretaries of the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect.

(iv) It shall 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 may be able to bring such recommendations adequately before their respective Societies.

(v) The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results.

Chapter XII.

Amendments and New Rules.

Alterations. Any alterations in the Rules, and any amendments or new Rules that may be proposed by the Council or individual Members, shall be notified to the General Committee on the first day of the Annual Meeting, and referred forthwith to the Committee of Recommendations; and, on the report of that Committee, shall be submitted for approval at the last meeting of the General Committee.

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

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
VISCOUNT MILTON, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S., F.R.S.E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S., F.R.S.E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S., F.R.S.E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.

PRESIDENTS	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK August 17, 1843.	The Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.

The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S., F.R.S.E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S., F.R.S.E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society. BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society. HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge. William Lassell, Esq., F.R.S., F.R.S.E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S., F.R.S.E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

Presidents	Vice-Presidents	Local Secretaries
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford. BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.

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

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

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S., F.R.S.E. Professor Allman, M.D., LL.D., F.R.S.L., F.R.S.E., F.L.S	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.

ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., LL.D., F.R.S. L. & E. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc. LL.D. F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.
SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. E. R. Wodehouse, Esq., M.P. Colonel R. P. Laurie, C.B., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord-Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord-Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.

SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon.M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S. The Right Hon. W. L. Jackson, M.P. Sir James Kitson, Bart., M.Inst.C.E. The Mayor of Leeds Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieutenant of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland His Grace the Duke of Newcastle The Right Hon. Lord Belper The Mayor of Nottingham The Right Hon. Sir W. R. Grove, F.R.S. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford. The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford. The Mayor of Oxford. Sir W. R. Anson, D.C.L., Warden of All Souls College. Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine The Rev. B. Price, D.D., F.R.S., Sedleian Professor of Natural Philosophy. Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.
CAPTAIN SIR DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S. IPSWICH, September 11, 1895.	The Most Hon. the Marquis of Bristol, M.A., Lord-Lieutenant of the County of Suffolk The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, Sec.R.S., Lord-Lieutenant of Essex The Right Hon. Lord Gwydyr, M.A., High Steward of Ipswich The Right Hon. Lord Henniker, F.S.A. The Right Hon. Lord Rendlesham J. H. Bartlet, Esq., Mayor of Ipswich Sir G. G. Stokes, Bart., D.C.L., F.R.S. Dr. E. Frankland, D.C.L., F.R.S. Professor G. H. Darwin, M.A., F.R.S. Felix T. Cobbold, Esq., M.A.	G. H. Hewetson, Esq. S. A. Notcutt, Esq., B.A., LL.M. B.Sc. E. P. Ridley, Esq.
SIR JOSEPH LISTER, Bart., D.C.L., LL.D., President of the Royal Society LIVERPOOL, September 16, 1896.	The Right Hon. the Earl of Derby, G.C.B., Lord Mayor of Liverpool. The Right Hon. the Earl of Sefton, K.G., Lord-Lieutenant of Lancashire Sir W. B. Forwood, J.P. Sir Henry E. Roscoe, D.C.L., F.R.S. The Principal of University College, Liverpool W. Rathbone, Esq., LL.D. W. Crookes, Esq., F.R.S., V.P.C.S. T. H. Ismay, Esq., J.P., D.L. Professor A. Liversidge, F.R.S.	Professor W. A. Herdman, F.R.S. Isaac C. Thompson, Esq., F.L.S. W. E. Willink, Esq.
SIR JOHN EVANS, K.C.B., D.C.L., LL.D., Sc.D., Treas.R.S., F.S.A., For.Sec.G.S. TORONTO, August 18, 1897.	His Excellency the Right Hon. the Earl of Aberdeen, G.C.M.G., Governor-General of the Dominion of Canada The Right Hon. Lord Rayleigh, M.A., D.C.L., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S., F.R.S.E. The Hon. Sir Wilfrid Laurier, G.C.M.G., Prime Minister of the Dominion of Canada His Honour the Lieutenant-Governor of the Province of Ontario The Hon. the Premier of the Province of Ontario The Hon. the Minister of Education for the Province of Ontario The Hon. Sir Charles Tupper, Bart., G.C.M.G., C.B., LL.D. The Hon. Sir Donald A. Smith, G.C.M.G., LL.D., High Commissioner for Canada Sir William Dawson, C.M.G., F.R.S. The Mayor of Toronto Professor J. Loudon, M.A., LL.D., President of the University of Toronto	Professor A. B. Macallum, M.B., Ph.D. B. E. Walker, Esq., F.G.S. J. S. Willison, Esq.

SIR WILLIAM CROOKES, F.R.S., V.P.C.S. BRISTOL, September 7, 1898.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Rev. the Lord Bishop of Bristol, D.D. The Right Hon. Sir Edward Fry, D.C.L., F.R.S., F.S.A. Sir F. J. Bramwell, Bart., D.C.L., LL.D., F.R.S. The Right Worshipful the Mayor of Bristol The Principal of University College, Bristol The Master of the Society of Merchant Venturers of Bristol John Beddoe, Esq., M.D., LL.D., F.R.S. Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.S.A., F.G.S.	Arthur Lee, Esq., J.P. Bertram Rogers, Esq., M.D.
PROFESSOR SIR MICHAEL FOSTER, K.C.B., M.D., D.C.L., LL.D., Sec. R.S. DOVER, September 13, 1899.	His Grace the Lord Archbishop of Canterbury, D.D. The Most Hon. the Marquis of Salisbury, K.G., M.A., D.C.L., F.R.S. The Mayor of Dover The Major-General Commanding the South-Eastern District The Right Hon. A. Akers-Douglas, M.P. The Very Rev. F. W. Farrar, D.D., F.R.S., Dean of Canterbury Sir J. Norman Lockyer, K.C.B., F.R.S. Professor G. H. Darwin, M.A., LL.D., F.R.S., Pres. R.A.S.	E. Wollaston Knocker, Esq., C.B. W. H. Pendlebury, Esq., M.A.
PROFESSOR SIR WILLIAM TURNER, M.B., D.Sc., D.C.L., LL.D., F.R.S. BRADFORD, September 5, 1900.	The Right Hon. the Earl of Scarbrough, Lord-Lieutenant of the West Riding of Yorkshire His Grace the Duke of Devonshire, K.G., D.C.L., LL.D., F.R.S. The Most Hon. the Marquis of Ripon, K.G., G.C.S.I., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Lord Masham His Worship the Mayor of Bradford The Hon. H. E. Butler, Lord of the Manor, Bradford Sir Alexander Binnie, M.Inst.C.E., F.G.S. Professor A. W. Rücker, M.A., D.Sc., Sec.R.S. Dr. T. E. Thorpe, Sc.D., F.R.S., Pres.C.S. Principal N. Bodington, Litt D., Vice-Chancellor of the Victoria University Professor L. C. Miall, F.R.S.	Ramsden Bacchus, Esq. J. E. Fawcett. Esq., J.P. Frederick Stevens, Esq.
PROFESSOR A. W. RÜCKER, M.A., LL.D., D.Sc., Sec.R.S. GLASGOW, September 11, 1901.	The Right Hon. the Earl of Glasgow, G.C.M.G. The Right Hon. the Lord Blythswood, LL.D., D.L. The Right Hon. the Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S. Samuel Chisholm, Esq., the Hon. the Lord Provost of Glasgow Very Rev. R. Herbert Story, D.D., LL.D., Principal of the University of Glasgow Sir John Maxwell Stirling-Maxwell, Bart., M.P., D.L. Sir Andrew Noble, K.C.B., D.C.L., F.R.S. Sir Archibald Geikie, D.C.L., LL.D., F.R.S. Sir W. T. Thiselton-Dyer, K.C.M.G., C.I.E., F.R.S. James Parker Smith, Esq., M.P., D.L. John Inglis, Esq., LL.D. Professor John Cleland, M.D., LL.D., D.Sc., F.R.S.	Sir J. D. Marwick, LL.D., D.L., F.R.S.E. Professor John Young, M.D. Professor Magnus Maclean, D.Sc., F.R.S.E.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR JAMES DEWAR, M.A., LL.D., D.Sc., F.R.S. BELFAST, September 10, 1902.	His Grace the Duke of Abercorn, K.G., H.M. Lieutenant of the County of Donegal The Marquis of Londonderry, K.G., H.M. Lieutenant of the City of Belfast Sir Francis Macnaghten, Bart., H.M. Lieutenant of the County of Antrim The Right Hon. the Earl of Shaftesbury, D.L. The Right Hon. the Earl of Rosse, K.P., D.C.L., LL.D., F.R.S. The Right Hon. Thomas Sinclair, D.Lit. Sir William Quartus Ewart, Bart., M.A. The Lord Mayor of Belfast The President of Queen's College, Belfast Professor E. Ray Lankester, M.A., F.R.S. Professor Peter Redfern, M.D.	John Brown, Esq., F.R.S. Godfrey W. Ferguson, Esq. Professor Maurice FitzGerald, B.A.
SIR NORMAN LOCKYER, K.C.B., LL.D., F.R.S., Correspondant de l'Institut de France. SOUTHPORT, September 9, 1903.	The Right Hon. the Earl of Derby, K.G., G.C.B. The Right Hon. the Earl of Crawford and Balcarres, K.T., LL.D., F.R.S. The Right Hon. the Earl Spencer, K.G., LL.D., Chancellor of the Victoria University The Right Hon. the Earl of Sefton The Right Hon. the Earl of Lathom Sir Henry Roscoe, B.A., Ph.D., LL.D., D.C.L., F.R.S. Sir George A. Pilkington Alfred Hopkinson, Esq., LL.D., K.C., Vice-Chancellor of the Victoria University T. T. L. Scarisbrick, Esq., Mayor of Southport E. Marshall Hall, Esq., K.C., M.P. for Southport Charles H. B. Hesketh, Esq. Charles Scarisbrick, Esq., J.P. Charles Weld Blundell, Esq.	Harold Brodrick, Esq., M.A. J. Ernest Jarratt, Esq.
The RIGHT HON. A. J. BALFOUR, D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh. CAMBRIDGE, August 17, 1904.	His Grace the Duke of Devonshire, K.G., LL.D., F.R.S., Chancellor of the University of Cambridge Alexander Peckover, Esq., LL.D., Lord Lieutenant of Cambridgeshire Arthur Hall, Esq., M.A., D.L., High Sheriff of Cambridgeshire and Huntingdonshire The Right Rev. the Lord Bishop of Ely, D.D. The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, D.C.L., LL.D., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S. The Rev. F. H. Chase, D.D., Vice-Chancellor of the University and President of Queen's College, Cambridge The Very Rev. H. Montagu Butler, D.D., Master of Trinity Mrs. Sidgwick, Principal of Newnham College, Cambridge J. H. Chesshyre Dalton, Esq., M.D., Mayor of Cambridge Robert Stephenson, Esq., Chairman of the Cambridgeshire County Council Joseph Martin, Esq., Chairman of the Isle of Ely County Council P. H. Young, Esq., Deputy Mayor of Cambridge	S. R. Ginn, Esq., D.L. A. Hutchinson, Esq., M.A. A. C. Seward, Esq., M.A., F.R.S. S. Skinner, Esq., M.A. J. E. L. Whitehead, Esq., M.A.

PROFESSOR G. H. DARWIN, M.A., LL.D., Ph.D., F.R.S. SOUTH AFRICA, August 15, 1905.	His Excellency the Right Hon. the Earl of Selborne, G.C.M.G., High Commissioner for South Africa The Right Hon. Lord Milner, G.C.B., G.C.M.G., late High Commissioner for South Africa His Excellency the Hon. Sir Walter F. Hely-Hutchinson, G.C.M.G., Governor of Cape Colony His Excellency Colonel Sir Henry E. McCallum, K.C.M.G., R.E., Governor of Natal His Excellency Captain the Hon. Sir Arthur Lawley, K.C.M.G., Lieutenant-Governor, Transvaal His Excellency Major Sir H. J. Goold-Adams, K.C.M.G., Lieutenant-Governor, Orange River Colony His Honour Sir W. H. Milton, K.C.M.G., Administrator of Southern Rhodesia. Sir Charles H. T. Metcalfe, Bart., M.A. Sir David Gill, K.C.B., LL.D., F.R.S., H.M. Astronomer, Cape Colony Theodore Reunert, M.Inst.C.E. The Mayor of Cape Town The Mayor of Johannesburg The President of the Philosophical Society of South Africa The Mayor of Durban The Mayor of Pietermaritzburg The Mayor of Bloemfontein The Mayor of Pretoria The Mayor of Kimberley The Mayor of Bulawayo	*Cape Town:—* Professor J. C. Beattie, D.Sc., F.R.S.E. E. J. Cattell, J.P. J. R. Finch. Rev. Wm. Flint, D.D. E. Hope Jones. W. L. Sclater, M.A. *Johannesburg:—* W. E. Cursons F. Rowland. *Central Organising Committee for South Africa:—* *Chairman.*—Sir David Gill, K.C.B., F.R.S. *Hon. Secretaries.*—J. D. F. Gilchrist, M.A., Ph.D. (Cape Town); W. Cullen (Johannesburg).
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. The Right Hon. the Earl of Feversham The Right Rev. the Lord Bishop of Ripon, D.D., D.C.L. The Right Hon. Lord Avebury, D.C.L., LL.D., F.R.S. The Right Hon. Lord Wenlock, G.C.S.I., G.C.I.E., K.C.B. Sir Hugh Bell, Bart. Sir George S. Gibb Tempest Anderson, M.D., D.Sc., President of the Yorkshire Philosophical Society. John Stephenson Rowntree	Henry Craven. O. E. Elmhirst.
SIR DAVID GILL, K.C.B., LL.D., F.R.S., Hon. F.R.S.E. LEICESTER, July 31, 1907.	His Grace the Duke of Rutland, Lord Lieutenant of Leicestershire Richard Dalgliesh, J.P., D.L., High Sheriff of Leicestershire Sir Edward Wood, J.P., Mayor of Leicester The Right Hon. the Earl of Dysart The Right Hon. the Earl Howe, G.C.V.O. The Right Rev. the Lord Bishop of Peterborough, D.D. The Right Rev. the Bishop of Leicester, D.D. Sir Oliver Lodge, D.Sc., LL.D., F.R.S., Principal of the University of Birmingham Herbert Ellis, President of the Leicester Literary and Philosophical Society	Alfred Colson, M.Inst.C.E. E. V. Hiley.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
FRANCIS DARWIN, M.A., M.B., LL.D., F.R.S. DUBLIN, September 2, 1908.	Right Hon. Alderman Gerald O'Reilly, Lord Mayor of Dublin Right Hon. Sir Samuel Walker, Bart., Lord Chancellor of Ireland Right Hon. Augustine Birrell, M.P., Chief Secretary to the Lord Lieutenant of Ireland Right Hon. the Earl of Meath, K.P., His Majesty's Lieutenant for the County of Dublin Right Hon. Lord Castletown of Upper Ossory, K.P., Chancellor of the Royal University of Ireland Anthony Traill, M.D., LL.D., Provost of Trinity College, Dublin Very Rev. William Delany, LL.D., President of University College, Dublin Right Hon. Viscount Iveagh, K.P., LL.D., F.R.S. Right Hon. Lord Ardilaun, D.L., LL.D., President of the Royal Dublin Society Francis A. Tarleton, LL.D., President of the Royal Irish Academy Right Hon. Mr. Justice Madden, M.A., LL.D., Vice-Chancellor of the University of Dublin Sir Christopher Nixon, Bart., M.D., LL.D., Vice-Chancellor of the Royal University of Ireland T. W. Russell, M.P., Vice-President of the Department of Agriculture and Technical Instruction in Ireland	Joseph McGrath, LL.D. John Mulligan, J. P. Professor W. H. Thompson, D.Sc., M.D. Professor W. E. Thrift, M.A.

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1883–95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895–97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHÄFER, F.R.S.
1897–1900 Prof. SCHÄFER, F.R.S., and Sir W. C. ROBERTS-AUSTEN, F.R.S.
1900–02 Sir W. C. ROBERTS-AUSTEN, F.R.S., and Dr. D. H. SCOTT, F.R.S.
1902–03 Dr. D. H. SCOTT, F.R.S., and Major P. A. MACMAHON, F.R.S.
1903 Major P. A. MACMAHON, F.R.S., and Prof. W. A. HERDMAN, F.R.S.

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Date and Place	Presidents	Secretaries

MATHEMATICAL AND PHYSICAL SCIENCES.

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

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

SECTION A.—MATHEMATICS AND PHYSICS.

Date and Place	Presidents	Secretaries
1835. Dublin	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
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1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork	Prof. M'Culloch, M.R.I.A.	J. Nott, Prof. Stevelly.
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1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
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1847. Oxford	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
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1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S. .	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Dr. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, A. Johnson, O. J. Lodge, D. MacAlister.
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.

Date and Place	Presidents	Secretaries
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath.........	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw, H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff......	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford	Prof. A. W. Rücker, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.
1895. Ipswich ...	Prof. W. M. Hicks, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, G. T. Walker, W. Watson.
1896. Liverpool...	Prof. J. J. Thomson, M.A., D.Sc., F.R.S.	Prof. W. H. Heaton, J. L. Howard, Prof. A. Lodge, G. T. Walker, W. Watson.
1897. Toronto ...	Prof. A. R. Forsyth, M.A., F.R.S.	Prof. W. H. Heaton, J. C. Glashan, J. L. Howard, Prof. J. C. McLennan.
1898. Bristol......	Prof. W. E. Ayrton, F.R.S. ...	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.—*Dep. of Astronomy*, 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. —*Dep. of Astronomy*, 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. —*Dep. of Astronomy*, 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.—*Dep. of Astronomy and Meteorology*, 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.—*Sub-Section of Astronomy and Cosmical Physics*, 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. SouthAfrica	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.
1907. Leicester ...	Prof. A. E. H. Love, M.A., F.R.S.	E. E. Brooks, Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter.
1908. Dublin	Dr. W. N. Shaw, F.R.S.	Dr. W. G. Duffield, Dr. L. N. G. Filon, E. Gold, Prof. J. A. McClelland, Prof. A. W. Porter, Prof. E. T. Whittaker.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

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

SECTION B.—CHEMISTRY AND MINERALOGY.

Date and Place	Presidents	Secretaries
1835. Dublin	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool	Michael Faraday, F.R.S.	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838 Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth	Dr. Daubeny, F.R.S.	J. Prideaux, R. Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork	Prof. Apjohn, M.R.I.A.	R. Hunt, Dr. Sweeny.
1844. York	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S.	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford	Prof. B. C. Brodie, F.R.S.	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath	W. Odling, M.B., F.R.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.

Date and Place	Presidents	Secretaries
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. 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.

Date and Place	Presidents	Secretaries
1895. Ipswich ...	Prof. R. Meldola, F.R.S.	E. H. Fison, Arthur Harden, C. A. Kohn, J. W. Rodger.
1896. Liverpool...	Dr. Ludwig Mond, F.R.S. ...	Arthur Harden, C. A. Kohn.
1897. Toronto ...	Prof. W. Ramsay, F.R.S.......	Prof. W. H. Ellis, A. Harden, C. A. Kohn, Prof. R. F. Ruttan.
1898. Bristol	Prof. F. R. Japp, F.R.S.	C. A. Kohn, F. W. Stoddart, T. K. Rose.
1899. Dover	Horace T. Brown, F.R.S.......	A. D. Hall, C. A. Köhn, 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. Henderson, J. Ohm, Prof. W. J. Pope.
1904. Cambridge	Prof. Sydney Young, F.R.S....	Dr. M. O. Forster, Prof. G. G. Henderson, Dr. H. O. Jones, Prof. W. J. Pope.
1905. South Africa	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.
1907. Leicester ...	Prof. A. Smithells, F.R.S. ...	Dr. E. F. Armstrong, Prof. A. W. Crossley, J. H. Hawthorn, Dr. F. M. Perkin.
1908. Dublin	Prof. F. S. Kipping, F.R.S. ...	Dr. E. F. Armstrong, Dr. A. McKenzie, Dr. F. M. Perkin, Dr. J. H. Pollock.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

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

SECTION C.—GEOLOGY AND GEOGRAPHY.

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

Date and Place	Presidents	Secretaries
1844. York.........	Henry Warburton, Pres. G. S.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A. F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, F.R.S.	S. Benson, Prof. Oldham, Prof. Ramsay
1849. Birmingham	Sir Charles Lyell, F.R.S.......	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.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull.........	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	J. Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, 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. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B., 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,

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

Date and Place	Presidents	Secretaries
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol......	Dr. T. Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S. F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, F.R.S., F.G.S....	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath.........	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff......	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford......	L. Fletcher, M.A., F.R.S. ...	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.
1895. Ipswich ...	W. Whitaker, B.A., F.R.S. ...	F. A. Bather, G. W. Lamplugh, H. A. Miers, Clement Reid.
1896. Liverpool...	J. E. Marr, M.A., F.R.S.	J. Lomas, Prof. H. A. Miers, C. Reid.
1897. Toronto ...	Dr. G. M. Dawson, C.M.G., F.R.S.	Prof. A. P. Coleman, G. W. Lamplugh, Prof. H. A. Miers.
1898. Bristol......	W. H. Hudleston, F.R.S.	G. W. Lamplugh, Prof. H. A. Miers, H. Pentecost.
1899. Dover	Sir 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. South Africa	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.

Date and Place	Presidents	Secretaries
1906. York.........	G. W. Lamplugh, F.R.S.	H. L. Bowman, Rev. W. L. Carter, Rev. W. Johnson, J. Lomas.
1907. Leicester...	Prof. J. W. Gregory, F.R.S....	Dr. F. W. Bennett, Rev. W. L. Carter, Prof. T. Groom, J. Lomas.
1908. Dublin......	Prof. John Joly, F.R.S.	Rev. W. L. Carter, J. Lomas, Prof. S. H. Reynolds, H. J. Seymour.

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.

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. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

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

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

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S., 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.

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

Date and Place	Presidents	Secretaries
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. E. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. E. 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.
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.

Date and Place	Presidents	Secretaries
1866. Nottingham	Prof. Huxley, F.R.S.—*Dep. of Physiol.*, Prof. Humphry, F.R.S.—*Dep. of Anthropol.*, A. R. Wallace.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter......	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh.	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.

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

Date and Place	Presidents	Secretaries
1874. Belfast......	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres.R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, F.R.S.—*Dep. of Anth.*, Prof. Rolleston, F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister.—*Dep. of Anthropol.*, F. Galton, F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S. —*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, F.R.S.—*Dep. of Anat. & Physiol.*, F. M. Balfour, F.R.S.—*Dep. of Anthropol.*, F. W. Rudler.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	R. Owen, F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S. —*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, F.L.S. —*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal[1]...	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.

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

Date and Place	Presidents	Secretaries
1888. Bath.........	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, S. J. Hickson, F. W. Oliver, H. Wager, H. Marshall Ward.
1891. Cardiff......	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, W. Stirling, H. Wager.
1893. Nottingham[1]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, J. B. Farmer, Prof. W. A. Herdman, S. J. Hickson, W. B. Ransom, W. L. Sclater.
1894. Oxford[2] ...	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W. A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

SECTION D (*continued*).—ZOOLOGY.

1895. Ipswich ...	Prof. W. A. Herdman, F.R.S.	G. C. Bourne, H. Brown, W. E. Hoyle, W. L. Sclater.
1896. Liverpool...	Prof. E. B. Poulton, F.R.S. ...	H. O. Forbes, W. Garstang, W. E. Hoyle.
1897. Toronto ...	Prof. L. C. Miall, F.R.S.	W. Garstang, W. E. Hoyle, Prof. E. E. Prince.
1898. Bristol......	Prof. W. F. R. Weldon, F.R.S.	Prof. R. Boyce, W. Garstang, Dr. A. J. Harrison, W. E. Hoyle.
1899. Dover	Adam Sedgwick, F.R.S.	W. Garstang, J. Graham Kerr.
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.
1907. Leicester ...	Dr. W. E. Hoyle, M.A..........	Dr. J. H. Ashworth, L. Doncaster, E. E. Lowe, Dr. H. W. M. Tims.
1908. Dublin......	Dr. S. F. Harmer, F.R.S.......	Dr. J. H. Ashworth, L. Doncaster, Prof. A. Fraser, Dr. H. W. M. Tims.

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

Date and Place	Presidents	Secretaries

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

Date and Place	Presidents	Secretaries
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.

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

SECTION E.—PHYSIOLOGY.

Date and Place	Presidents	Secretaries
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. Southampton.	Prof. Owen, M.D., F.R.S.	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford [1]	Prof. Ogle, M.D., F.R.S.	T. K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

Date and Place	Presidents	Secretaries
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. Birmingham [2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

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

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

Date and Place	Presidents	Secretaries
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.

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

[2] *Vide* note on page lxxiv.

Date and Place	Presidents	Secretaries

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.
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 Crawfurd, F.R.S.........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.........	J.W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham.	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter......	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S.........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S......	H. W. Bates, E. C. Rye, R. O. Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B.	H. W. Bates, F. E. Fox, E. C. Rye.

Date and Place	Presidents	Secretaries
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R S.E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham.	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.........	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff......	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford......	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.
1895. Ipswich ...	H. J. Mackinder, M.A., F.R.G.S.	John Coles, H. N. Dickson, Dr. H. R. Mill, W. A. Taylor.
1896. Liverpool...	Major L. Darwin, Sec. R.G.S.	Col. F. Bailey, H. N. Dickson, Dr. H. R. Mill, E. C. DuB. Phillips.
1897. Toronto ...	J. Scott Keltie, LL.D.	Col. F. Bailey, Capt. Deville, Dr. H. R. Mill, J. B. Tyrrell.
1898. Bristol	Col. G. Earl Church, F.R.G.S.	H. N. Dickson, Dr. H. R. Mill, H. C. Trapnell.
1899. Dover	Sir John Murray, F.R.S.	H. N. Dickson, Dr. H. O. Forbes, Dr. H. R. Mill.
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.

Date and Place	Presidents	Secretaries
1907. Leicester ...	George G. Chisholm, M.A. ...	E. Heawood, O. J. R. Howarth, E. A. Reeves, T. Walker.
1908. Dublin......	Major E. H. Hills, C.M.G., R.E.	W. F. Bailey, W. J. Barton, O. J. R. Howarth, E. A. Reeves.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

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

SECTION F.—STATISTICS.

1835. Dublin......	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol......	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon.........	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham.	Henry Hallam, F.R.S..........	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	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.

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

Date and Place	Presidents	Secretaries
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1895. Ipswich ...	L. L. Price, M.A.	E. Cannan, Prof. E. C. K. Gonner, H. Higgs.
1896. Liverpool...	Rt. Hon. L. Courtney, M.P....	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1897. Toronto ...	Prof. E. C. K. Gonner, M.A.	E. Cannan, H. Higgs, Prof. A. Shortt.
1898. Bristol	J. Bonar, M.A., LL.D..........	E. Cannan, Prof. A. W. Flux, H. Higgs, W. E. Tanner.
1899. Dover	H. Higgs, LL.B.	A. L. Bowley, E. Cannan, Prof. A. W. Flux, Rev. G. Sarson.
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.
1907. Leicester...	Prof. W. J. Ashley, M.A.......	Prof. S. J. Chapman, D. H. Macgregor, H. O. Meredith, T. S. Taylor.
1908. Dublin......	W. M. Acworth, M.A.	W. G S. Adams, Prof. S. J. Chapman, Prof. D. H. Macgregor, H. O. Meredith.
	Sub-section of Agriculture—Rt. Hon. Sir H. Plunkett.	A. D. Hall, Prof. J. Percival, J. H. Priestley, Prof. J. Wilson.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham.	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth...	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York.........	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S..........	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford......	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.

Date and Place	Presidents	Secretaries
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
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham.	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, A. Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	C. Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	J. Abernethy, F.R.S.E..........	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport .	J. Brunlees, Pres. Inst. C.E. ...	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P. Inst. C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.

Date and Place	Presidents	Secretaries
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham.	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath.........	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne.	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff.....	T. Forster Brown, M.Inst.C.E.	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford......	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.
1895. Ipswich ...	Prof. L. F. Vernon-Harcourt, M.A., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke. W. B. Marshall, P. G. M. Stoney.
1896. Liverpool...	Sir Douglas Fox, V.P.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, S. Dunkerley, W. B. Marshall.
1897. Toronto ...	G. F. Deacon, M.Inst.C.E. ...	Prof. T. Hudson Beare, Prof. Callendar, W. A. Price.
1898. Bristol......	Sir J. Wolfe-Barry, K.C.B., F.R.S.	Prof. T. H. Beare, Prof. J. Munro, H. W. Pearson, W. A. Price.
1899. Dover	Sir W. White, K.C.B., F.R.S.	Prof. T. H. Beare, W. A. Price, H. E. Stilgoe.
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. South Africa	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. Triffit.
1907. Leicester...	Prof. Silvanus P. Thompson, F.R.S.	Prof. E. G. Coker, A. C. Harris, W. A. Price, H. E. Wimperis.
1908. Dublin......	Dugald Clerk, F.R.S.	Prof. E. G. Coker, Dr. W. E. Lilly, W. A. Price, H. E. Wimperis.

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.

[1] The title of Section G was changed to Engineering.

Date and Place	Presidents	Secretaries
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.
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. Shrubsall.
1907. Leicester...	D. G. Hogarth, M.A.............	C. J. Billson, E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrubsall.
1908. Dublin......	Prof. W. Ridgeway, M.A. ...	E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrubsall, L. E. Steele.

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.

Date and Place	Presidents	Secretaries
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.
1907. Leicester ...	Dr. A. D. Waller, F.R.S.	Dr. N. H. Alcock, J. Barcroft, Prof J. S. Macdonald, Dr. A. Warner.
1908. Dublin	Dr. J. Scott Haldane, F.R.S.	Prof. D. J. Coffey, Dr. P. T. Herring Prof. J. S. Macdonald, Dr. H. E. Roaf.

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. ...... *Sub-section of Agriculture*—Dr. W. Somerville.	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. Burtt, R. P. Gregory, Prof. A. G. Tansley, Prof. R. H. Yapp.
1907. Leicester ...	Prof. J. B. Farmer, F.R.S. ...	W. Bell, R. P. Gregory, Prof. A. G. Tansley, Prof. R. H. Yapp.
1908. Dublin	Dr. F. F. Blackman, F.R.S....	Prof. H. H. Dixon, R. P. Gregory, A. G. Tansley, Prof. R. H. Yapp.

SECTION L.—EDUCATIONAL SCIENCE.

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.

Date and Place	Presidents	Secretaries
1907. Leicester ...	Sir Philip Magnus, M.P.	W. D. Eggar, Prof. R. A. Gregory, J. S. Laver, Hugh Richardson.
1908. Dublin	Prof. L. C. Miall, F.R.S.	Prof. E. P. Culverwell, W. D. Eggar, George Fletcher, Prof. R. A. Gregory, 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.
1907. Leicester...	H. J. Mackinder, M.A..........	F. W. Rudler, I.S.O.
1908. Dublin	Prof. H. A. Miers, F.R.S.......	W. P. D. Stebbing.

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.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.

Date and Place	Lecturer	Subject of Discourse
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive Substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham.	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their Changes of Form.
	G. B. Airy, F.R.S., 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.
	Robert Hunt, F.R.S............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform Research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G.B.Airy,F.R.S.,Astron.Royal	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.

Date and Place	Lecturer	Subject of Discourse
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham.	J. Beete Jukes, F.R.S.........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S.......	The Results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S. ...	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.......	Some Recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford............	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast......	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The 'Challenger' Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S............	The New Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S....	The Electric Discharge its Forms and its Functions.

Date and Place	Lecturer	Subject of Discourse
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick.	Galvanic and Animal Electricity.
1884. Montreal ...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E..........	The Great Ocean Basins.
1886. Birmingham.	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton	Explorations in Central Africa.
1888. Bath.........	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.........	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. M. Marshall, F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells, B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford......	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.
	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.
1895. Ipswich ...	Prof. S. P. Thompson, F.R.S.	Magnetism in Rotation.
	Prof. Percy F. Frankland, F.R.S.	The Work of Pasteur and its various Developments.
1896. Liverpool...	Dr. F. Elgar, F.R.S.	Safety in Ships.
	Prof. Flinders Petrie, D.C.L.	Man before Writing.
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.
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.

Date and Place	Lecturer	Subject of Discourse
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.
	C. Vernon Boys, F.R.S.	Some Surface Actions of Fluids.
Durban ...	Douglas W. Freshfield.........	The Mountains of the Old World.
	Prof. W. A. Herdman, F.R.S.	Marine Biology.
Pietermaritz-burg	Col. D. Bruce, C.B., F.R.S....	Sleeping Sickness.
	H. T. Ferrar	The Cruise of the 'Discovery.'
Johannesburg	Prof. W. E. Ayrton, F.R.S. ...	The Distribution of Power.
	Prof. J. O. Arnold...............	Steel as an Igneous Rock.
Pretoria ...	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.
1907. Leicester ...	W. Duddell, F.R.S.	The Ark and the Spark in Radio-telegraphy.
	Dr. F. A. Dixey..................	Recent Developments in the Theory of Mimicry.
1908. Dublin......	Prof. H. H. Turner, F.R.S. ...	Halley's Comet.
	Prof. W. M. Davis.	The Lessons of the Colorado Canyon.

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 Powe.
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.

Date and Place	Lecturer	Subject of Lecture
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath	Sir John Lubbock, Bart., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes	Spontaneous Combustion.
1894. Oxford	Prof. W. J. Sollas, F.R.S. ...	Geologies and Deluges.
1895. Ipswich ...	Dr. A. H. Fison	Colour.
1896. Liverpool...	Prof. J. A. Fleming, F.R.S....	The Earth a Great Magnet.
1897. Toronto ...	Dr. H. O. Forbes	New Guinea.
1898. Bristol	Prof. E. B. Poulton, F.R.S. ...	The ways in which Animals Warn their Enemies and Signal to their Friends.
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.
1907. Leicester ...	Prof. H. A. Miers, F.R.S.......	The Growth of a Crystal.
1908. Dublin	Dr. A. E. H. Tutton, F.R.S.	The Crystallisation of Water.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, 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.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, C.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	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13
1901, Sept. 11	Glasgow	Prof. A. W. Rücker, 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
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24

* 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*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
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
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.
¶ Including 848 Members of the South African Association.

ANALYSIS OF ATTENDANCES AT THE ANNUAL MEETINGS, 1831–1906.

[*The total attendances for the years* 1832, 1835, 1843, *and* 1844 *are unknown.*]

Average attendance at 72 *Meetings* : 1855.

	Average Attendance
Average attendance at 5 Meetings beginning during *June, between* 1833 *and* 1860	1260
Average attendance at 3 Meetings beginning during *July, between* 1841 *and* 1851	947
Average attendance at 28 Meetings beginning during *August, between* 1836 *and* 1906	1978*
Average attendance at 34 Meetings beginning during *September, between* 1831 *and* 1903	1933
Attendance at 1 Meeting held in *October, Cambridge*, 1862 . .	1161

Meetings beginning during August and September.

Average attendance at—

4 Meetings beginning during the 1st week in *August* (1st– 7th) .	1905
5 ,, ,, ,, ,, 2nd ,, ,, ,, (8th–14th) .	2130
8 ,, ,, ,, ,, 3rd ,, ,, ,, (15th–21st) .	1761 †
11 ,, ,, ,, ,, 4th ,, ,, ,, (22nd–31st) .	2094

Average attendance at—

11 Meetings beginning during the 1st week in *September* (1st– 7th).	2082
16 ,, ,, ,, ,, 2nd ,, ,, ,, (8th–14th).	1860
5 ,, ,, ,, ,, 3rd ,, ,, ,, (15th–21st).	2206
2 ,, ,, ,, ,, 4th ,, ,, ,, (22nd–30th).	1025

Meetings beginning during June, July, and October.

Attendance at 1 Meeting (1845, June 19) beginning during the 3rd week in *June* (15th–21st)	1079
Average attendance at 4 Meetings beginning during the 4th week in *June* (22nd–30th)	1306
Attendance at 1 Meeting (1851, July 2) beginning during the 1st week in *July* (1st–7th)	710
Average attendance at 2 Meetings beginning during the 3rd week in *July* (15th–21st)	1066
Attendance at 1 Meeting (1862, October 1) beginning during the 1st week in *October* (1st–7th)	1161

* Average attendance at 29 Meetings, *including* South Africa, 1905 (August 15–September 1): 1983.

† Average attendance at 9 Meetings, *including* South Africa, 1905 (August 15–September 1): 1802.

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

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

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

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on Long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	0
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars (Lacaille)	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

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

1843.

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

	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

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

1845.

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

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory...	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain ...	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

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

1848.

	£	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
	£275	1	8

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
	£159	19	6

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
	£345	18	0

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
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)........................	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland ...	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates......	10	0	0
	£304	6	7

1853.

	£	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
	£205	0	0

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
	£380	19	7

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
	£480	16	4

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
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

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

1859.

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

1860.

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

1861.

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

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland Coasts	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

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

1864.

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

1865.

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

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee...........	50	0	0
British Rainfall..................	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed ...	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation ...	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards...........	100	0	0
Malta Caves Exploration......	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall................ ..	25	0	0
DredgingAberdeenshireCoast	25	0	0
Dredging Hebrides Coast ...	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	29	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches ...	30	0	0
Palestine Exploration Fund...	100	0	0
	£1750	13	4

1867.

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

1868.

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

1869.

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

	£	s.	d.
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal 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
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

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

1873.

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

1874.

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

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

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

1877.

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

1878.

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

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

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

1881.

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

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe ...	25	0	0
Circulation of Underground Waters	15	0	0
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station ...	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra ...	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee...	50	0	0
	£1126	1	11

1883.

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

1884.

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

1885.

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

1886.

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

1887.

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

1888.

	£	s.	d.
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands	20	0	0
	£1511	0	5

1889.

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

1890.

	£	s.	d.
Electrical Standards	12	17	0
Electrolysis	5	0	0
Electro-optics	50	0	0
Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	10	0	0
Circulation of Underground Waters	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northampton	25	0	0
Botanical Station at Peradeniya	25	0	0

	£	s.	d.
Experiments with a Tow-net	4	3	9
Naples Zoological Station ...	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes	20	0	0
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel...	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire ...	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1029	10	0

1892.

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

1893.

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

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

1894.

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

1895.

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

1896.

	£	s.	d.
Photographs of Meteorological Phenomena	15	0	0
Seismological Observations	80	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Uniformity of Size of Pages of Transactions, &c.	5	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	2	6	1
Electrolytic Quantitative Analysis	10	0	0
The Carbohydrates of Barley Straw	50	0	0
Reprinting Discussion on the Relation of Agriculture to Science	5	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	2	0	0
Investigation of a Coral Reef by Boring and Sounding	10	0	0
Examination of Locality where the Cetiosaurus in the Oxford Museum was found	25	0	0
Palæolithic Deposits at Hoxne	25	0	0
Fauna of Singapore Caves	40	0	0
Age and Relation of Rocks near Moreseat, Aberdeen	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	50	0	0
Zoology of the Sandwich Islands	100	0	0
African Lake Fauna	100	0	0
Oysters under Normal and Abnormal Environment	40	0	0
Climatology of Tropical Africa	10	0	0
Calibration and Comparison of Measuring Instruments	20	0	0
Small Screw Gauge	10	0	0
North-Western Tribes of Canada	100	0	0
Lake Village at Glastonbury	30	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies Committee	30	0	0
	£1104	6	1

1897.

	£	s.	d.
Mathematical Tables	25	0	0
Seismological Observations	100	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Electrolysis and Electro-chemistry	50	0	0
Electrolytic Quantitative Analysis	10	0	0
Isomeric Naphthalene Derivatives	50	0	0
Erratic Blocks	10	0	0
Photographs of Geological Interest	15	0	0
Remains of the Irish Elk in the Isle of Man	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	9	10	8
Zoological Bibliography and Publication	5	0	0
Index Generum et Specierum Animalium	100	0	0
Zoology and Botany of the West India Islands	40	0	0
The Details of Observations on the Migration of Birds	40	0	0
Climatology of Tropical Africa	20	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Silchester Excavation	20	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	180	0	0
Oysters and Typhoid	30	0	0
Physiological Applications of the Phonograph	15	0	0
Physiological Effects of Peptone and its Precursors	20	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	25	0	0
	£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
Healthy and Unhealthy Oysters ...	30	0	0
Climatology of Tropical Africa	10	0	0
State Monopolies in other Countries ...	15	0	0
Small Screw Gauge ...	20	0	0
North-Western Tribes of Canada ...	75	0	0
Lake Village at Glastonbury	37	10	0
Silchester Excavation ...	7	10	0
Ethnological Survey of Canada	75	0	0
Anthropology and Natural History of Torres Straits ...	125	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0
Fertilisation in Phæophyceæ	15	0	0
Corresponding Societies Committee ...	25	0	0
	£1212	0	0

1899.

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

1900.

	£	s.	d.
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
Wave-length Tables ...	5	0	0
Electrolytic Quantitative Analysis ...	5	0	0

	£	s.	d.
Isomorphous Sulphonic Derivatives of Benzene	20	0	0
The Nature of Alloys	30	0	0
Photographs of Geological Interest	10	0	0
Remains of Elk in the Isle of Man	5	0	0
Pleistocene Fauna and Flora in Canada	10	0	0
Movements of Underground Waters of Craven	40	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	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
Future Dealings in Raw Produce	2	10	0
Silchester Excavation	10	0	0
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
Ethnography of the Malay Peninsula	25	0	0
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
Vascular Supply of Secreting Glands	10	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Com.	20	0	0
	£1072	10	0

1901.

	£	s.	d.
Electrical Standards	45	0	0
Seismological Observations	75	0	0
Wave-length Tables	4	14	0
Isomorphous Sulphonic Derivatives of Benzene	35	0	0
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 Phlegræan 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
Morphology, Ecology, and Taxonomy of Podostemaceæ	20	0	0
Corresponding Societies Committee	15	0	0
	£920	9	11

1902.

	£	s.	d.
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 Ascidians 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
	£947	0	0

1903.

	£	s.	d.
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
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
	£845	13	2

1904.

	£	s.	d.
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
	£887	18	11

1905.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	40	0	0
Magnetic Observations at Falmouth	50	0	0
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	20	0	0
Aromatic Nitramines	25	0	0
Fauna and Flora of the British Trias	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	75	0	0
Development of the Frog	10	0	0
Investigations in the Indian Ocean	150	0	0
Trade Statistics	4	4	8
Researches in Crete	75	0	0
Anthropometric Investigations on Egyptian Troops	10	0	0
Excavations on Roman Sites in Britain	10	0	0
AnthropometricInvestigations	10	0	0
Age of Stone Circles	30	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	30	0	0
Ductless Glands	40	0	0
Botanical Photographs	3	17	6
Physiology of Heredity	35	0	0
Structure of Fossil Plants	50	0	0
Corresponding Societies Committee	20	0	0
	£928	2	2

1906.

	£	s.	d.
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
AnthropometricInvestigations 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

1907.

	£	s.	d.
Electrical Standards	50	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	40	0	0
Magnetic Survey of South Africa	25	7	6
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	30	0	0
Life Zones in British Carboniferous Rocks	10	0	0
Erratic Blocks	10	0	0
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone of South-West England	15	0	0
Correlation and Age of South African Strata, &c.	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Sexual Cells	1	11	8
Oscillations of the Land Level in the Mediterranean Basin	50	0	0
Gold Coinage in Circulation in the United Kingdom	8	19	7

	£	s.	d.
Anthropometric Investigations in the British Isles...	10	0	0
Metabolism of Individual Tissues	45	0	0
The Ductless Glands	25	0	0
Effect of Climate upon Health and Disease	55	0	0
Physiology of Heredity	30	0	0
Research of South African Cycads	35	0	0
Botanical Photographs	5	0	0
Structure of Fossil Plants	5	0	0
Marsh Vegetation	15	0	0
Corresponding Societies Committee	16	14	1
	£757	12	10

1908.

	£	s.	d.
Seismological Observations	40	0	0
Further Tabulation of Bessel Functions	15	0	0
Investigation of Upper Atmosphere by means of Kites...	25	0	0
Meteorological Observations on Ben Nevis	25	0	0
Geodetic Arc in Africa	200	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	40	0	0
Transformation of Aromatic Nitramines	30	0	0
Erratic Blocks	17	16	6
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
Pre-Devonian Rocks	10	0	0
Exact Significance of Local Terms	5	0	0
Composition of Charnwood Rocks	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Hereditary Experiments	10	0	0
Fauna of Lakes of Central Tasmania	40	0	0
Investigations in the Indian Ocean	50	0	0
Exploration in Spitsbergen	30	0	0
Gold Coinage in Circulation in the United Kingdom	3	7	6
Electrical Standards	50	0	0
Glastonbury Lake Village	30	0	0
Excavations on Roman Sites in Britain	15	0	0
Age of Stone Circles	50	0	0
Anthropological Notes and Queries	40	0	0
Metabolism of Individual Tissues	40	0	0
The Ductless Glands	13	14	8
Effect of Climate upon Health and Disease	35	0	0
Body Metabolism in Cancer	30	0	0
Electrical Phenomena and Metabolism of *Arum spadices*	10	0	0
Marsh Vegetation	15	0	0
Succession of Plant Remains	18	0	0
Corresponding Societies Committee	25	0	0
	£1157	18	8

Report of the Council, 1907–1908.

I. The Council have adopted the following RESOLUTIONS :—

(i) "The President and Council of the British Association desire to express their profound regret at the death of LORD KELVIN, O.M., G.C.V.O., D.C.L., LL.D., F.R.S., &c., and to place on record their sense of the great services he rendered to the Association in important offices. They recall that he was President of the Association in 1871 at Edinburgh, and was President of Section A on no fewer than five occasions. His constant attendance at the Meetings and the leading part he was in the habit of taking in the proceedings of Section A will always be remembered. His loss, indeed, seems to be irreparable.

"The President and Council furthermore desire to express their sympathy with Lady Kelvin and other members of the family in their bereavement."

(ii) "The President and Council of the British Association desire to express their deep regret at the death of SIR JOHN EVANS, K.C.B., D.C.L., LL.D., F.R.S., and to record their high appreciation of the services he rendered to the Association as a member of the Council during a long period of years, as President of the Association in 1897, and as a Sectional President in 1878 and in 1890.

"The President and Council furthermore desire to express their sincere sympathy with Lady Evans and the family in their bereavement."

(iii) "The President and Council of the British Association desire to express their deep regret at the death of the Earl of Rosse, Chancellor of the University of Dublin, and to offer their sincere sympathy with the Countess of Rosse and the family in their bereavement."

Sir David Gill, *President*, represented the Association at the DARWIN-WALLACE CELEBRATION on July 1 by the Linnean Society of London.

Mr. Francis Darwin, F.R.S., *President-Elect*, will represent the Association at the commemoration next year by the University of Cambridge of the centenary of Charles Darwin's birth.

II. PROFESSOR J. J. THOMSON, F.R.S., has been unanimously nominated by the Council to fill the office of President of the Association for 1909 (Winnipeg Meeting).

III. The following NOMINATIONS are made by the Council :—

(i) As an additional *Vice-President* of the Association for the Dublin Meeting : Right Hon. Augustine Birrell, M.P. ; and as *Local Secretary*, John Mulligan, in place of Charles E. Martin, deceased.

(ii) Professor H. A. Miers, F.R.S., *Chairman*, Professor Grenville Cole, *Vice-Chairman*, and W. P. D. Stebbing, *Secretary*, of the CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES to be held at Dublin.

(iii) Members of the *Corresponding Societies Committee* for the ensuing year: *Chairman*, Mr. W. Whitaker; *Secretary*, Mr. W. P. D. Stebbing; Rev. J. O. Bevan, Sir Edward Brabrook, Dr. J. G. Garson, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Professor R. Meldola, Dr. H. R. Mill, Mr. F. W. Rudler, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.

IV. A Report has been received from the CORRESPONDING SOCIETIES COMMITTEE, together with the list of 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, 1908.

V. The following RESOLUTION, referred to the Council by the General Committee at Leicester, has been considered and acted upon:—

From Sections L and H jointly.

"That, in view of the national importance of obtaining data on the question of physical deterioration, this Association urges upon the Government the pressing necessity of instituting, in connection with the medical inspection of school children, a system of periodic measurement which will provide definite information on their physical condition and development."

A Committee, consisting of Sir Edward Brabrook, Mr. Sidney Hartland, and Professor D. J. Cunningham, was appointed to report on this proposal; and the following has been received and adopted by the Council:—

"Your Committee, appointed to consider and report on the joint Resolution from Sections L and H at the Leicester Meeting, report as follows:—

"(i) The memorial referred to in the Resolution was presented to the Board of Education; and since then a Minute has been issued by that Board recommending a system of anthropometric observation of the children in Elementary Schools.

"(ii) Your Committee consider that the Minute concedes as much as the Board could reasonably be expected to have adopted as a preliminary and experimental measure; and that, therefore, no further action on the part of the Council is at the present time called for."

VI. A RESOLUTION, referred to the Council by the General Committee at Leicester, has been received

From the Conference of Delegates:—

"That it is desirable (1) to obtain information as to the present state of things in Britain in connection with Photo Survey work; (2) to publish instructions or give advice for the

> execution of a scientific Photographic Survey; and (3) to endeavour to found, or promote, a Photo-Record of the town and district in which the British Association holds its Annual Meeting."

This Resolution was remitted to the Corresponding Societies Committee for consideration and report to the Council; and the proposal in regard to promoting a photo-record of the city and district in which the Association holds its Annual Meeting was forwarded to the Dublin Executive Committee for their consideration. It is understood that the Local Committee will act upon this suggestion.

The report of the Corresponding Societies Committee on this subject is contained in their Annual Report to the Council.

VII. The Resolution by the Committee of Section D, remitted to the Council by the General Committee at Leicester, was considered; and the Council resolved that no action be taken.

VIII. A proposed new RULE, referred to the Council by the General Committee at Leicester for consideration and report, to the effect that the Council shall have power to remove a Member or Associate for conduct tending to bring the Association into disrepute, has been considered.

A Committee, consisting of Sir Edward Brabrook, Dr. Carey Foster, Dr. Chalmers Mitchell, and the General Officers, was appointed to draft a Rule for the consideration of the Council; and the following Report has been received and adopted:—

> "The Committee appointed by the Council to draft a new Rule, giving the Council powers of ejection from the Association, recommend the addition of the following words to the concluding paragraph of Chapter X. (1) of the Rules—namely, after the word 'exclusion' to add:
>
> > "... by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued."

In accordance with this suggestion the Council recommend that the second paragraph of Rule 1, Chapter X., as amended in the above Report, be sanctioned by the General Committee to read as follows:—

> "Every person admitted as a Member or an Associate shall conform to the Rules and Regulations of the Association, any infringement of which on his part may render him liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued."

IX. The Council have authorised Section F (Economic Science and Statistics) to form a SUB-SECTION FOR AGRICULTURE for the Dublin Meeting, with a Chairman, Vice-Chairmen, and Secretariat to deal with its transactions.

X. The Council have received the following communication, proposing the constitution of a Section for ASTRONOMY AND COSMICAL PHYSICS :—

10 MORETON GARDENS, S.W.
December 31, 1907.

To SIR DAVID GILL, K.C.B., F.R.S., *President.*

DEAR SIR DAVID GILL,

The signatories of this letter are those who have acted as Chairmen of the Sub-Section of Section A for Astronomy and Cosmical Physics. Our purpose is to ask you to bring before the Association a proposal for the constitution of a separate Section for the group of Sciences included in the title "Astronomy and Cosmical Physics."

2. The ground for our request is that the applications of Mathematics and Physics in Astronomy, Geodesy, Meteorology, Terrestrial Magnetism, Atmospheric Electricity, and Seismology, together with the treatment of those subjects from the point of view of the organisation and collection of observations of natural phenomena, attract papers sufficient in number and importance to deserve a separate Section.

3. The separation of these subjects from Mathematics and Experimental Physics would have the further advantage that more time would be found for the newer developments of those subjects the discussion of which is now unduly restricted.

4. Under existing conditions there is not time to deal with the papers on Astronomy and Meteorology prepared for the Meetings, and no encouragement can be offered to the comparatively few students of the other observational Sciences associated with Mathematics and Physics, to bring the progress in their subjects to the notice of the Association. In consequence, these subjects lose the advantage of the discussion of questions at a Meeting of the Association, and the important influence of a Sectional Committee in matters of organisation and co-operation.

5. For a number of years a Sub-Section for Astronomy and Cosmical Physics was formed, but it has been discontinued since the Meeting at Cambridge in 1904. It is not necessary to consider here the reasons for this suspension, which originated perhaps with the difficulties of managing a Sub-Section during the expeditional Session of 1905 to the Cape. But the reasons are certainly not connected with any ill-success of the experiment tried. There was always plenty of work for the Sub-Section, and, in the interval, there has been noteworthy progress, especially on the lines of international co-operation, in the observational Sciences. Consequently, the remedy for the congestion of business in Section A, which met with general acceptance up to 1904, is no longer adequate. A separate Section for the observational Sciences to which Mathematics and Physics are applied has become necessary.

6. In common with all students of Mathematics and Physics, we recognise the advantage of the opportunity which is afforded by the Meetings of the British Association for the students of a particular branch of Science to keep in touch with the progress in allied branches and with the developments of Mathematics and Experimental Physics. The

advantage is, however, only nominal when the discussion of questions has to be so rigorously curtailed that the proceedings are only intelligible to those who are already expert in the particular questions. The restriction of the consideration of Sciences of wide scope to a day, or half a day, discourages the attendance of Members of the Association interested in those Sciences. The influence of the Association would be made more effective and more beneficial, both directly and indirectly, by the rearrangement which we wish to propose. Nothing short of that rearrangement would provide for the adequate representation and discussion of the questions which form the subject of papers before the Section or of proposals before the Sectional Committee.

We are, dear Sir David Gill,

Yours faithfully,

(*Signed*) ARTHUR SCHUSTER.
" H. H. TURNER.
" W. N. SHAW.
" JOHN ELIOT.

The Council resolved, without prejudice, to remit this proposal to the Organising Committee of Section A, for their consideration and advice.

XI. The following Invitation from SHEFFIELD for the year 1910 will be presented to the General Committee at Dublin, and be supported by a joint deputation representing the City Council and Sheffield University :—

January 24, 1908.

DEAR SIR,—We are directed by the Sheffield City Council and the Sheffield University to cordially extend to the British Association for the Advancement of Science, through its Executive Council, an invitation to hold its Annual Meeting in Sheffield in the year 1910.

Sheffield has an estimated population of 463,222. In addition to the University, the Mappin Art Gallery, and several museums, there is the Ruskin Museum at Meersbrook Park. The city is noted for its great steel, iron, and kindred industries, where armour plates, silver and electro plate, cutlery, and other goods are manufactured.

It is scarcely necessary to add that, should the invitation be accepted, every effort will be made by the representative life of the city to make the Meeting an unqualified success.

Pray be good enough to bring this invitation before your Executive Council, and at your convenience acquaint us with their decision.

We are, Yours faithfully,

(*Signed*) HARRY P. MARSH, *Lord Mayor.*
" NORFOLK, *Chancellor of the University of Sheffield.*

XII. The following Invitation from PORTSMOUTH for the year 1911 will be presented to the General Committee at Dublin, and be supported by a deputation representing the Town of Portsmouth :—

June 1, 1908.

SIR,—I am instructed by the Corporation of Portsmouth to invite the British Association for the Advancement of Science to hold their Annual Meeting at Portsmouth in 1911.

A Local Committee will be appointed in order to make all necessary arrangements, if the invitation can be accepted by the Association.

I am, Sir,

Your obedient Servant,

(*Signed*) A. HELLARD, *Town Clerk.*

XIII. The Council have received reports from the General Treasurer during the past year. His ACCOUNTS from July 1, 1907, to June 30, 1908, have been audited, and are presented to the General Committee.

XIV. In accordance with the Regulations, the retiring Members of the COUNCIL are: *by seniority*—Professor D. J. Cunningham and Dr. A. C. Haddon; *by least attendance*—Professor J. N. Langley, C. Vernon Boys, and Professor Wyndham Dunstan.

The Council recommend the re-election of the other ordinary Members, with the addition of those whose names are distinguished by an asterisk in the following list, leaving two vacancies to be filled up by the General Committee:—

Abney, Sir W., K.C.B., F.R.S.
Anderson, Tempest, M.D., D.Sc.
Bourne, Professor G. C., D.Sc.
Bowley, A. L., M.A.
Brabrook, Sir Edward, C.B.
Brown, Dr. Horace T., F.R.S.
*Brunton, Sir Lauder, Bart., Sc.D., F.R.S.
*Close, Major C. F., R.E., C.M.G.
Dyson, Professor F. W., F.R.S.
Forsyth, Professor A. R., F.R.S.
Glazebrook, Dr. R. T., F.R.S.
Hartland, E. Sidney, F.S.A.
Hawksley, C., M.Inst.C.E.
Hogarth, D. G., M.A.
McKendrick, Professor J. G., F.R.S.
Mitchell, Dr. P. Chalmers, F.R.S.
Poulton, Professor E. B., F.R.S.
Prain, Lieut.-Colonel D., C.I.E., F.R.S.
Sherrington, Professor C. S., F.R.S.
Shipley, A. E., F.R.S.
*Tutton, Dr. A. E. H., F.R.S.
Watts, Professor W. W., F.R.S.
Woodward, Dr. A. Smith, F.R.S.

XV. The General Officers have been nominated by the Council for reappointment.

XVI. The Council recommend that, on the occasion of the Meeting of the Association at Winnipeg, the President, Vice-Presidents, and Officers of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE be invited to attend as honorary Members for the year; and, further, that all Fellows and Members of the American Association be admitted Members of the British Association on the same terms as old Annual Members—namely, on payment of 1*l.*, without the contribution of an admission fee, and with the additional privilege of receiving a free copy of the Report of the Meeting.

XVII. The following have been admitted as Members of the GENERAL COMMITTEE:—

Auden, Dr. G. A.
Bernacchi, Mr. L. C.
Boeddicker, Dr. Otto.
Boulton, Dr. W. S.
Crooke, Mr. William.
Fraser, Miss Helen.
Hill, Mr. Arthur W.
Porter, Professor J. B.
Reid, Dr. Archdall.
Stansfield, Mr. Herbert.
Young, Dr. George.
Young, Dr. W. H.

Dr. THE GENERAL TREASURER'S ACCOUNT,

1907–1908. RECEIPTS.

				£	s.	d.
Balance brought forward				2362	18	6
Life Compositions (including Transfers)				419	0	0
New Annual Members' Subscriptions				264	0	0
Annual Subscriptions				637	0	0
Sale of Associates' Tickets				653	0	0
Sale of Ladies' Tickets				251	0	0
Sale of Publications				190	19	7
Dividend on Consols				154	8	4
Dividend on India 3 per Cents.				102	12	0
Great Indian Peninsula Railway 'B' Annuity				24	15	3
Interest on Deposit				20	9	0
Unexpended Balances returned:—	£	s.	d.			
Researches in Crete	50	0	0			
Life Zones in British Carboniferous Rocks...	5	15	9			
Effect of Climate upon Health and Disease	4	4	5			
Erratic Blocks	17	16	6			
Faunal Succession in the Carboniferous Limestone of South-West England	1	13	6			
Correlation and Age of South African Strata	7	16	9			
				87	6	11
				£5167	9	7

Investments.

	£	s.	d.
$2\frac{1}{2}$ per Cent. Consolidated Stock	6501	10	5
India 3 per Cent. Stock	3600	0	0
£73 Great Indian Peninsula Railway 'B' Annuity (cost)	1493	6	6
	11,594	16	11
Sir Frederick Bramwell's Gift:—			
$2\frac{1}{2}$ per Cent. Self-cumulating Consolidated Stock	65	6	1
	£11,660	3	0

JOHN PERRY, *General Treasurer.*

from July 1, 1907, to June 30, 1908. *Cr.*

1907–1908. PAYMENTS.

	£	s.	d.	£	s.	d.
Rent and Office Expenses				96	14	1
Salaries, &c.				788	4	4
Printing, Binding, &c.				972	0	5
Expenses of Leicester Meeting				140	8	2
Purchase of £73 Great Indian Peninsula Railway 'B' Annuity				1493	6	6
Payment of Grants made at Leicester:						
Seismological Observations	40	0	0			
Further Tabulation of Bessel Functions	15	0	0			
Investigation of the Upper Atmosphere by means of Kites	25	0	0			
Meteorological Observations on Ben Nevis	25	0	0			
Geodetic Arc in Africa	200	0	0			
Wave-length Tables of Spectra	10	0	0			
Study of Hydro-Aromatic Substances	30	0	0			
Dynamic Isomerism	40	0	0			
Transformation of Aromatic Nitramines	30	0	0			
Erratic Blocks	17	16	6			
Fauna and Flora of British Trias	10	0	0			
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0			
Pre-Devonian Rocks	10	0	0			
Exact Significance of Local Terms	5	0	0			
Composition of Charnwood Rocks	10	0	0			
Table at the Zoological Station at Naples	100	0	0			
Index Animalium	75	0	0			
Hereditary Experiments	10	0	0			
Fauna of Lakes of Central Tasmania	40	0	0			
Investigations in the Indian Ocean	50	0	0			
Exploration in Spitsbergen	30	0	0			
Gold Coinage in Circulation in the United Kingdom	3	7	6			
Electrical Standards	50	0	0			
Glastonbury Lake Village	30	0	0			
Excavations on Roman Sites in Britain	15	0	0			
Age of Stone Circles	50	0	0			
Anthropological Notes and Queries	40	0	0			
Metabolism of Individual Tissues	40	0	0			
The Ductless Glands	13	14	8			
Effect of Climate upon Health and Disease	35	0	0			
Body Metabolism in Cancer	30	0	0			
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0			
Marsh Vegetation	15	0	0			
Succession of Plant Remains	18	0	0			
Corresponding Societies Committee	25	0	0			
				1157	18	8
				£4648	12	2
Balance at Bank of England (Western Branch)	564	2	8			
Add Cheque not credited	1	0	0			
	565	2	8			
Less Cheques not presented	45	5	0			
	519	17	8			
Less Petty Cash overspent	1	0	3			
				518	17	5
				£5167	9	7

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.*
July 28, 1908.

General Meetings at Dublin.

On Wednesday, September 2, at 8.30 P.M., in the Great Hall of the Royal University, Sir David Gill, K.C.B., F.R.S., resigned the office of President to Mr. Francis Darwin, M.B., LL.D., F.R.S., who took the Chair and delivered an Address, for which see p. 3.

On Thursday, September 3, at 8 P.M., a Conversazione was held at Leinster House.

On Friday, September 4, at 8.30 P.M., in the Great Hall of the Royal University, Professor H. H. Turner, F.R.S., delivered a Discourse on 'Halley's Comet.'

On Monday, September 7, at 8.30 P.M., in the Great Hall of the Royal University, Professor W. M. Davis delivered a Discourse on 'The Lessons of the Colorado Canyon.'

On Tuesday, September 8, a Garden Party was given by the Local Committee in the Gardens of the Royal Zoological Society.

On Wednesday, September 9, at 3 P.M., the concluding General Meeting was held in the Royal University Buildings, when the following Resolutions were adopted :—

1. That a cordial vote of thanks be given to the Lord Mayor and Corporation of the City of Dublin for the reception which they have accorded to the British Association.

2. That a cordial vote of thanks be given (i) to the Provost and Senior Fellows of Trinity College and to the Senate of the Royal University of Ireland ; (ii) to the governing bodies of the public institutions which have granted the use of their buildings for sectional proceedings ; and (iii) to the authorities of the schools and works thrown open to the inspection of the members of the Association.

3. That a cordial vote of thanks be given to the Local Executive Officers and Committees for the admirable arrangements made for the meetings.

4. That the grateful thanks of the Association be given to the citizens of Dublin for the generous hospitality shown to its members on the occasion of this meeting.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE DUBLIN MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Dr. W. N. Shaw, F.R.S. *Vice-Presidents.*—Prof. W. F. Barrett, F.R.S.; Prof. W. S. Burnside, F.T.C.D.; Prof. C. H. Lees, F.R.S.; Prof. A. E. H. Love, F.R.S.; Prof. F. Purser, F.T.C.D.; Prof. H. H. Turner, F.R.S. *Secretaries.*—Prof. A. W. Porter, B.Sc. (*Recorder*); Dr. W. Geoffrey Duffield; Dr. L. N. G. Filon; E. Gold, M.A.; Prof. J. A. McClelland; Prof. E. T. Whittaker, F.R.S.

SECTION B.—CHEMISTRY.

President.—Prof. F. S. Kipping, F.R.S. *Vice-Presidents.*—Sir Charles A. Cameron, M.D.; Prof. W Noel Hartley, F.R.S.; Prof. A. Smithells, F.R.S.; Prof. Sydney Young, F.R.S. *Secretaries.*—Dr. E. F. Armstrong (*Recorder*); Dr. Alex. McKenzie; Dr. F. M. Perkin; Dr. James H. Pollok.

SECTION C.—GEOLOGY.

President.—Prof. John Joly, F.R.S. *Vice-Presidents.*—Prof. Grenville A. Cole; Prof. W. M. Davis; Sir A. Geikie, K.C.B., Sec. R.S.; Prof. J. W. Gregory, F.R.S.; A. Smith Woodward, F.R.S. *Secretaries.*—J. Lomas (*Recorder*); Rev. W. Lower Carter, M.A.; Prof. S. H. Reynolds, M.A.; H. J. Seymour, B.A.

SECTION D.—ZOOLOGY.

President.—Dr. S. F. Harmer, F.R.S. *Vice-Presidents.*—Dr. W. E. Hoyle Prof. A. A. W. Hubrecht; Prof. E. W. MacBride, F.R.S.; Dr. R. F. Scharff; A. E. Shipley, F.R.S. *Secretaries.*—H. W. Marett Tims, M.D. (*Recorder*); J. H. Ashworth, D.Sc.; L. Doncaster, M.A.; Prof. Alex. Fraser, M.B.

SECTION E.—GEOGRAPHY.

President.—Major E. H. Hills, C.M.G., R.E. *Vice-Presidents.*—J. Bolton; Major C. F. Close, R.E., C.M.G.; Major Leonard Darwin, R.E.; Prof. W. M. Davis; Rev. W. Spotswood Green, C.B., M.A.; Dr. A. J. Herbertson; Captain H. G. Lyons, R.E., F.R.S. *Secretaries.*—O. J. R. Howarth, M.A. (*Recorder*); W. F. Bailey, C.B.; W. J. Barton, B.A.; E. A. Reeves.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—W. M. Acworth. *Vice-Presidents.*—Prof. W. J. Ashley; Prof. C. F. Bastable; Sir H. Llewellyn Smith, K.C.B. *Secretaries.*—Prof. S. J. Chapman, M.A. (*Recorder*); W. G. S. Adams, M.A.; Prof. D. H. Macgregor, M.A.; H. O. Meredith.

SUB-SECTION.—AGRICULTURE.

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Research Committees appointed by the General Committee at the Dublin Meeting: September 1908.

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants
Section A.—MATHEMATICS AND PHYSICS.		£ s. d.
Seismological Observations.	*Chairman.*—Professor H H. Turner. *Secretary.*—Dr. J. Milne. 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, Professors J. W. Judd, C. G. Knott, and R. Meldola, Mr. R. D. Oldham, Professor J. Perry, Mr. W. E. Plummer, Professor J. H. Poynting, Mr. Clement Reid, and Mr. Nelson Richardson.	60 0 0
To co-operate with the Royal Meteorological Society in the Investigation of the Upper Atmosphere by means of Kites.	*Chairman.*—Dr. W. N. Shaw. *Secretary.*—Mr. W. H. Dines. Mr. D. Archibald, Mr. C. Vernon Boys, Dr. R. T. Glazebrook, Dr. H. R. Mill, Professor J. E. Petavel, Dr. A. Schuster, and Dr. W. Watson.	10 0 0
To co-operate with the Committee of the Falmouth Observatory in their Magnetic Observations.	*Chairman.*—Sir W. H. Preece. *Secretary.*—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.	50 0 0
To aid the work of Establishing a Solar Observatory in Australia.	*Chairman.*—Sir David Gill. *Secretary.*—Dr. W. G. Duffield. Dr. W. J. S. Lockyer, Mr. F. McClean, and Professors A. Schuster and H. H Turner.	50 0 0
Section B.—CHEMISTRY.		
Preparing a new Series of Wavelength Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—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

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Study of Hydro-aromatic Substances.	*Chairman*.—Professor E. Divers. *Secretary*.—Professor A. W. Crossley. Professor W. H. Perkin, Dr. M. O. Forster, and Dr. Le Sueur.	15 0 0
Dynamic Isomerism.	*Chairman*.—Professor H. E Armstrong. *Secretary*.—Dr. T. M. Lowry. Professor Sydney Young, Dr. Desch, Dr. J. J. Dobbie, Dr. A. Lapworth, and Dr. M. O. Forster.	35 0 0
The Transformation of Aromatic Nitramines and allied substances, and its relation to Substitution in Benzene Derivatives.	*Chairman*.—Professor F. S. Kipping. *Secretary*.—Professor K. J. P. Orton. Dr. S. Ruhemann, Dr. A. Lapworth, and Dr. J. T. Hewitt.	10 0 0
Electroanalysis.	*Chairman*.—Professor F. S. Kipping. *Secretary*.—Dr. F. M. Perkin. Dr. G. T. Beilby, Dr. T. M. Lowry, Professor W. J. Pope, and Mr. H. J. S. Sand.	30 0 0
SECTION C.—GEOLOGY.		
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman*.—Mr. R. H. Tiddeman. *Secretary*.—Dr. A. R. Dwerryhouse. Dr. T. G. Bonney, Mr. F. M. Burton, Mr. F. W. Harmer, Rev. S. N. Harrison, Dr. J. Horne, Mr. J. Lomas, Professor W. J. Sollas, and Messrs. J. W. Stather and W. T. Tucker.	12 0 0
To report upon the Fauna and Flora of the Trias of the British Isles.	*Chairman*.—Professor W. A. Herdman. *Secretary*.—Mr. J. Lomas. Mr. H. C. Beasley, Mr. E. T. Newton, Professor A. C. Seward, Mr. W. A. E. Ussher, Professor W. W. Watts, and Dr. A. Smith Woodward.	8 0 0
To investigate the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, and at various localities in the East Riding of Yorkshire.	*Chairman*.—Mr. G W. Lamplugh. *Secretary*.—Mr. J. W. Stather. Dr. Tempest Anderson, Professor J. W. Carr, Rev. W. Lower Carter, Dr. A. R. Dwerryhouse, Mr. F. W. Harmer, Mr. J. H. Howarth, Rev. W. Johnson, and Messrs. G. W. B. Macturk, E. T. Newton, H. M. Platnauer, Clement Reid, and T. Sheppard.	11 0 0
To enable Mr. E. Greenly to complete his Researches on the Composition and Origin of the Crystalline Rocks of Anglesey.	*Chairman*.—Mr. A. Harker. *Secretary*.—Mr. E. Greenly. Mr. J. Lomas, Dr. C. A. Matley, and Professor K. J. P. Orton.	1 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To enable Dr. A. Vaughan to continue his Researches on the Faunal Succession in the Carboniferous Limestone in the British Isles.	*Chairman.*—Professor J. W. Gregory. *Secretary.*—Dr. A. Vaughan. Dr. Wheelton Hind and Professor W. W. Watts.	10 0 0
To excavate Critical Sections in the Palæozoic Rocks of Wales and the West of England.	*Chairman.*—Professor C. Lapworth. *Secretary.*—Mr. W. G. Fearnsides. Mr. J. Lomas, Dr. J. E. Marr, Professor W. W. Watts, and Mr. G. W. Williams.	15 0 0
To investigate the Microscopical and Chemical Composition of Charnwood Rocks.	*Chairman.* — Professor W. W. Watts. *Secretary.*—Dr. T. T. Groom. Dr. F. P. Bennett, Mr. C. Fox-Strangways, and Dr. Stracey.	2 0 0
The Investigation of Igneous and Associated Rocks of Glensaul and Lough Nafovey Areas, Cos. Mayo and Galway.	*Chairman.* — Professor W. W. Watts *Secretary.*—Professor S. H. Reynolds. Messrs. H. B. Muff and C. I. Gardiner.	20 0 0
To investigate the Ancient Salt Lakes and other Desert Phenomena at Biskra, Algeria, in particular relation to the British Trias.	*Chairman.*—Professor J. Joly. *Secretary.*—J. Lomas. Mr. Allorge, Dr. A. Hutchinson, and Professors Sollas and W. W. Watts.	50 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.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Rev. T. R. R. Stebbing. Sir E. Ray Lankester, Professor A. Sedgwick, Professor W. C. McIntosh, Dr. S. F. Harmer, and Mr. G. P. Bidder	75 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Dr. F. A. Bather. Dr. P. L. Sclater, Rev. T. R. R. Stebbing, Dr. W. E. Hoyle, the Hon. Walter Rothschild, and Lord Walsingham.	75 0 0
To enable Mr. Laurie to conduct Experiments in Inheritance.	*Chairman.* — Professor W. A. Herdman. *Secretary.*—Mr. Douglas Laurie. Mr. R. C. Punnett and Dr. H. W. Marett Tims.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To investigate the Feeding Habits of British Birds by a study of the contents of the crops and gizzards of both adults and nestlings, and by the collation of observational evidence, with the object of obtaining precise knowledge as to the economic status of many of our commoner birds affecting rural science.	*Chairman.*—Dr. A. E. Shipley. *Secretary.*—Mr. C. Gordon Hewitt. Messrs. J. N. Halbert, Robert Newstead, A. G. L. Rogers, and F. V. Theobald.	5 0 0
Section E.—GEOGRAPHY.		
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.	*Chairman.*—Sir John Murray. *Secretary.*—Mr. J. Stanley Gardiner. Captain E. W. Creak, Professors W. A. Herdman, S. J. Hickson, and J. W. Judd, Mr. J. J. Lister, Dr. H. R. Mill, and Dr. David Sharp.	35 0 0
The Quantity and Composition of Rainfall, and of Lake and River Discharge.	*Chairman.*—Sir John Murray. *Secretaries.*—Professor A. B. Macallum and Dr. A. J. Herbertson. 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
Section F.—ECONOMIC SCIENCE AND STATISTICS.		
The Amount of Gold Coinage in Circulation in the United Kingdom.	*Chairman.*—Mr. R. H. Inglis Palgrave. *Secretary.*—Mr. H. Stanley Jevons. Professor Edgeworth and Messrs. A.L. Bowley and D.H. Macgregor.	6 0 0
The Amount and Distribution of Income (other than Wages) below the Income-tax exemption limit in the United Kingdom.	*Chairman.*—Professor E. Cannan. *Secretary.*—Professor A. L. Bowley. Messrs. W. G. S. Adams and A. B. Clark and Professors F. Y. Edgeworth and H. B. Lees Smith.	15 0 0
Section G.—ENGINEERING.		
The Investigation of Gaseous Explosions, with special reference to Temperature.	*Chairman.*—Sir W. H. Preece. *Secretaries.*—Mr. Dugald Clerk and Professor B. Hopkinson. Professors W. A. Bone, F. W. Burstall, H. L. Callendar, E. G. Coker, W. E. Dalby, and H. B. Dixon, Drs. R. T. Glazebrook, J. A. Harker, and H. S. Hele-Shaw, Colonel H. C. L. Holden, Mr. J. E. Petavel, Captain H. Riall Sankey, and Profesors A. Smithells and W. Watson.	75 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
Section H.—ANTHROPOLOGY.		
		£ s. d.
To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.	*Chairman.*—Dr. R. Munro. *Secretary.*—Professor W. Boyd Dawkins. Professor W. Ridgeway and Messrs. Arthur J. Evans, C. H. Read, H. Balfour, and A. Bulleid.	5 0 0
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Professor R. C. Bosanquet. Sir Edward Brabrook, Dr. T. Ashby, Mr. D. G. Hogarth, and Professors W. Ridgeway and W. Boyd Dawkins.	57 0 0
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. H. Balfour. Lord Avebury, Professor W. Ridgeway, Dr. J. G. Garson, Dr. A. J. Evans, Dr. R. Munro, Professor Boyd Dawkins, and Mr. A. L. Lewis.	30 0 0
To prepare a New Edition of Notes and Queries in Anthropology.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Professor J. L. Myres. Professor D. J. Cunningham, Mr. E. N. Fallaize, Dr. A. C. Haddon, Mr. T. A. Joyce, and Drs. C. S. Myers, W. H. R. Rivers, C. G. Seligmann, and F. C. Shrubsall.	40 0 0
To conduct Archæological and Ethnological Researches in Crete.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Professor J. L. Myres. Professor R. C. Bosanquet, Dr. W. L. H. Duckworth, Dr. A. J. Evans, Professor A. Macalister, and Professor W. Ridgeway.	70 0 0
Section I.—PHYSIOLOGY.		
The Ductless Glands.	*Chairman.*—Professor Schäfer. *Secretary.*—Professor Swale Vincent. Professor A. B. Macallum, Dr. L. E. Shore, and Mrs. W. H. Thompson.	35 0 0
Body Metabolism in Cancer.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Dr. S. M. Copeman.	20 0 0
The Electrical Phenomena and Metabolism of *Arum Spadices.*	*Chairman.*—Professor A. D. Waller. *Secretary.*—Miss Sandars. Professor Gotch and Professor Farmer.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Rev. T. R. R. Stebbing. Sir E. Ray Lankester, Professor A. Sedgwick, Professor W. C. McIntosh, Dr. S. F. Harmer, and Mr. G. P. Bidder.	25 0 0
Reflex Muscular Rhythm.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Miss Buchanan.	10 0 0
To acquire further knowledge, Clinical and Experimental, concerning Anæsthetics, especially chloroform, ether, and alcohol, with special reference to deaths by, or during, anæsthesia, and their possible diminution.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Dr. Hewitt. Sir Frederick Treves.	25 0 0
Tissue Metabolism, for the investigation of the Metabolism of Special Organs.	*Chairman.*—Professor E. H. Starling. *Secretaries.*—Professor W. D. Brodie. Dr. J. S. Haldane.	20 0 0
Mental and Muscular Fatigue.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Dr. W. MacDougall. Professor J. S. MacDonald and Mr. H. Sackville Lawson.	40 0 0
SECTION K.—BOTANY.		
The Structure of Fossil Plants.	*Chairman.*—Dr. D. H. Scott. *Secretary.*—Professor F. W. Oliver. Mr. E. Newell Arber and Professors A. C. Seward and F. E. Weiss.	5 0 0
To carry out the scheme for the Registration of Negatives of Botanical Photographs.	*Chairman.*—Professor F. W. Oliver. *Secretary.*—Professor F. E. Weiss. Dr. W. G. Smith, Mr. A. G. Tansley, Dr. T. W. Woodhead, and Professor R. H. Yapp.	10 0 0
The Experimental Study of Heredity.	*Chairman.*—Mr. Francis Darwin. *Secretary.*—Mr. A. G. Tansley. Professors Bateson and Keeble.	30 0 0
The investigation of Symbiosis between Turbellarian Worms and Algæ.	*Chairman.*—Dr. F. F. Blackman. *Secretary.*—Professor F. E. Weiss. Professors Keeble and Nuttall.	10 0 0
A Botanical, Zoological, and Geological Survey of Clare Island.	*Chairman.*—Professor T. Johnson. *Secretary.*—Mr. R. Lloyd Praeger. Professor Grenville Cole, Dr. Scharff, and Mr. A. G. Tansley.	65 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
SECTION L.—EDUCATIONAL SCIENCE.		£ s. d
To report upon the Course of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.	*Chairman.*—Sir Philip Magnus. *Secretary.*—Mr. W. M. Heller. Sir W. de W. Abney, Mr. R. H. Adie, Professor H. E. Armstrong, Miss L. J. Clarke, Miss A. J. Cooper, Mr. George Fletcher, Professor R. A. Gregory, Principal Griffiths, Mr. A. D. Hall, Dr. A. J. Herbertson, Dr. C. W. Kimmins, Professor L. C. Miall, Professor J. Perry, Mrs. W. N. Shaw, Professor A. Smithells, Dr. Lloyd Snape, Sir H. R. Reichel, Mr. H. Richardson, and Professor W. W. Watts.	5 0 0
To consider and to advise as to the Curricula of Secondary Schools.	*Chairman.*—Sir Oliver Lodge. *Secretary.*—Mr. C. M. Stuart. Professor H. E. Armstrong, Mr. G. F. Daniell, Mr. W. D. Eggar, Professor J. J. Findlay, Dr. Gray, Professor R. A. Gregory, Principal Griffiths, Sir W. Huggins, Mr. O. H. Latter, Sir Philip Magnus, Professor H. A. Miers, Mr. T. E. Page, Professor J. Perry, Mr. Hugh Richardson, Professor M. E. Sadler, and Dr. A. E. Shipley.	5 0 0
CORRESPONDING SOCIETIES.		
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. W. P. D. Stebbing. Rev. J. O. Bevan, Sir Edward Brabrook, Dr. J. G. Garson, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Professor R. Meldola, Dr. H. R. Mill, Mr. F. W. Rudler, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.	21 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee
Section A.—MATHEMATICS AND PHYSICS.	
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.	*Chairman.*—Lord Rayleigh. *Secretary.*—Dr. R. T. Glazebrook. 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 Arthur Rücker, Professor H. L. Callendar, and Messrs. G. Matthey, A. P. Trotter, T. Mather, and F. E. Smith.
To continue the Magnetic Survey of South Africa commenced by Professors Beattie and Morrison.	*Chairman.*—Sir David Gill. *Secretary.*—Professor J. C. Beattie. Mr. S. S. Hough, Professor Morrison, and Professor A. Schuster.
To carry out a further portion of the Geodetic Arc of Meridian North of Lake Tanganyika.	*Chairman.*—Sir George Darwin. *Secretary.*—Sir David Gill. Major Close and Sir George Goldie.
The further Tabulation of Bessel Functions.	*Chairman.*—Professor M. J. M. Hill. *Secretary.*—Dr. L. N. G. Filon. Professor Alfred Lodge and Mr. J. W. Nicholson.
To report upon the provision for the Study of Astronomy, Meteorology (including Atmospheric Electricity), and Geophysics in the Universities of the British Empire.	*Chairman.*—Sir Arthur Rücker. *Secretary.*—Professor A. E. H. Love. Sir Oliver Lodge, Professors C. G. Knott, E. Rutherford, A. Schuster, J. J. Thomson, and E. T. Whittaker, Drs. W. G. Duffield and G. T. Walker, and Mr. R. T. A. Innes
To report on the present state of our Knowledge of the Upper Atmosphere as obtained by the use of Kites, Balloons, and Pilot Balloons.	Messrs. E. Gold and W. A. Harwood.
Section B.—CHEMISTRY.	
The Study of Isomorphous Sulphonic Derivatives of Benzene.	*Chairman.*—Professor H. A. Miers. *Secretary.*—Professor H. E. Armstrong. Professors W. P. Wynne and W. J. Pope.

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

Subject for Investigation, or Purpose	Members of Committee
SECTION C.—GEOLOGY.	
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretaries.*—Professors W. W. Watts and S. H. Reynolds. Dr. T. Anderson, Mr. G. Bingley, Dr. T. G. Bonney, Mr. H. Coates, Mr. C. V. Crook, Professor E. J. Garwood, Messrs. W. Gray, R. Kidston, and A. S. Reid, Dr. J. J. H. Teall, and Messrs. R. Welch, W. Whitaker, and H. B. Woodward.
To investigate and report on the Correlation and Age of South African Strata and on the question of a Uniform Stratigraphical Nomenclature.	*Chairman.*—Professor J. W. Gregory. *Secretary.*—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, Mr. F. P. Mennell, Dr. Molengraaff, Mr. A. J. C. Molyneux, Mr. A. W. Rogers, Mr. E. H. L. Schwarz, and Professor R. B. Young.
To determine the precise Significance of Topographical and Geological Terms used locally in South Africa.	*Chairman.*—Mr. G. W. Lamplugh. *Secretary.*—Dr. F. H. Hatch. Dr. G. Corstorphine and Messrs. A. Du Toit, A. P. Hall, G. Kynaston, F. P. Mennell, and A. W. Rogers.
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.	*Chairman.*—Dr. F. Du Cane Godman. *Secretary.*—Dr. David Sharp. Professor S. J. Hickson, Dr. P. L. Sclater, and Mr. Edgar A. Smith.
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.	*Chairman.*—Sir E. Ray Lankester. *Secretary.*—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, Professors C. Lloyd Morgan, E. B. Poulton, and A. Sedgwick, Mr. A. E. Shipley, and Rev. T. R. R. Stebbing.
To nominate competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman* and *Secretary.*—Professor A. Dendy. Sir E. Ray Lankester, Professor A. Sedgwick, and Professor Sydney H. Vines.

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

Subject for Investigation, or Purpose	Members of Committee
To enable Dr. J. W. Jenkinson to continue his Researches on the Influence of Salt and other Solutions on the Development of the Frog.	*Chairman.*—Professor G. C. Bourne. *Secretary.*—Dr. J. W. Jenkinson. Professor S. J. Hickson.

Section H.—ANTHROPOLOGY.

The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. H. S. Kingsford. Dr. T. Ashby, Dr. G. A. Auden, Mr. H. Balfour, Mr. E. N. Fallaize, Dr. H. O. Forbes, Dr. A. C. Haddon, Mr. E. S. Hartland, Mr. E. Heawood, Professor J. L. Myres, and Professor Flinders Petrie.
To organise Anthropometric Investigation in the British Isles.	*Chairman.*—Professor D. J. Cunningham. *Secretary.*—Mr. J. Gray. Dr. F. C. Shrubsall.
To conduct Archæological and Ethnological Investigations in Sardinia.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Professor R. C. Bosanquet. Dr. T. Ashby, Dr. W. L. H. Duckworth, Professor J. L. Myres, and Dr. F. C. Shrubsall.
To report upon Archæological Investigations in British East Africa.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Dr. A. C. Haddon. Mr. H. Balfour, Mr. C. T. Currelly, Dr. H. O. Forbes, and Professor J. L. Myres.
To establish a system of measuring Mental Characters.	*Chairman.*—Professor D. J. Cunningham. *Secretary.*—Mr. J. Gray. Miss Cooper and Drs. W. McDougall, C. S. Myers, W. H. R. Rivers, W. G. Smith, and Spearman.
To excavate Neolithic Sites in Northern Greece.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Professor J. L. Myres. Mr. J. P. Droop and Mr. D. G. Hogarth.

Section I.—PHYSIOLOGY.

The Effect of Climate upon Health and Disease.	*Chairman.*—Sir T. Lauder Brunton. *Secretary.*—Mr. J. Barcroft and Lieut.-Col. Simpson. Colonel Sir D. Bruce, Dr. S. G. Campbell, Sir Kendal Franks, Professor J. G. McKendrick, Sir A. Mitchell, Dr. C. F. K. Murray, Dr. Porter, Dr. J. L. Todd, Professor Sims Woodhead, Sir A. E. Wright, and the Heads of the Tropical Schools of Liverpool, London, and Edinburgh.

Section L.—EDUCATIONAL SCIENCE.

To take notice of, and report upon changes in, Regulations—whether Legislative, Administrative, or made by Local Authorities—affecting Secondary Education.	*Chairman.*—Sir Philip Magnus. *Secretary.*—Professor H. E. Armstrong. Sir William Bousfield, Mr. S. H. Butcher, Sir Henry Craik, Principal Griffiths, Sir Horace Plunkett, and Professor M. E. Sadler.

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

Subject for Investigation, or Purpose	Members of Committee
The Conditions of Health essential to the carrying on of the work of Instruction in Schools.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Mr. E. White Wallis. Sir E. Brabrook, Dr. C. W. Kimmins, Professor L. C. Miall, Miss A. J. Cooper, and Dr. Ethel Williams.
To inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.	*Chairman.*—Professor J. J. Findlay. *Secretary.*—Professor J. A. Green. Professors J. Adams and E. P. Culverwell, Mr. G. F. Daniell, Miss B. Foxley, Professor R. A. Gregory, Dr. C. W. Kimmins, Miss Major, Dr. T. P. Nunn, Dr. Spearman, Miss L. Edna Walter, and Dr. F. Warner.

Communications ordered to be printed in extenso.

The Theory of Wave-motion, by Professor Horace Lamb, and the Discussion thereon.

Colloid Chemistry. By Professor H. R. Procter.

Fatigue. By Dr. MacDougall.

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

From Sections A and E jointly.

That the Council should approach the Board of Agriculture with a view of ascertaining whether it is not possible for the Director-General of the Ordnance Survey of Great Britain and Ireland to undertake the remeasurement of the two principal arcs (meridional and longitudinal) as part of the current work of his Department.

From Section A.

That the Committee of Section A has received with interest information respecting the Meteorological and Astronomical Observatory at Bulawayo, and desires the Council to inform the Chartered Company of the importance from the scientific point of view attached to the continuance of the observations, and to express the hope that the Chartered Company will see its way to continue its financial support to the Observatory.

From Section D.

That the Council be requested to communicate a Resolution of Section D relating to Zoological Nomenclature to the International Commission on Nomenclature and to certain British scientific societies.

From Section H, supported by Section E

That the Council of the British Association be requested to lend their support to the project for an Imperial Bureau of Anthropology set on foot by the Royal Anthropological Institute. A memorial in favour of the scheme has already been numerously signed by distinguished Indian and Colonial administrators, heads and Parliamentary representatives of universities, principals of university colleges, anthropologists, directors of steamship companies, leading manufacturers and heads of other mercantile enterprises; and it will be presented to the Chancellor of the Exchequer in the coming session of Parliament by a deputation composed of some of the chief signatories.

From Section L.

1. That, in the opinion of this Committee, it is desirable that the Committee of Recommendations should meet on Tuesday afternoon with a view to the consideration of the papers recommended by Sectional Committees to be printed *in extenso* in the Annual Report.

2. That 1,000 reprints of the Report presented this year upon Practical Studies in Elementary Schools, with the introduction prepared by Sir Philip Magnus, be supplied to the Secretary of the Committee for distribution.

3. That 500 reprints of the Report presented this year upon the Sequence of Science Studies in Secondary Schools be supplied to the Secretary of the Sub-Committee for distribution.

From the Conference of Delegates.

The Conference desires to represent to the Committee of Recommendations that whenever a Committee of the British Association enters upon a local investigation notice should be given to any local scientific or archæological society, so as to enable that society to offer any co-operation that may be desirable.

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

1. That the following Committees be authorised to receive contributions from sources other than the Association:—

(i) 'To conduct Explorations with a view to ascertaining the Age of Stone Circles.' (Section H.)

(ii) 'On the Effect of Climate upon Health and Disease.' (Section I.)

2. That the Committee of Section G be authorised to publish the Report of their Committee on Gaseous Explosions, presented to and read before the Section on September 4, in such public journals as may seem desirable, in view of the purpose for which they are appointed.

3. That the Council be requested to consider the recommendation of the Committee of Section H, requesting them to direct that the Report of the Anthropometric Committee be printed in the annual volume in full, with the addition of the illustrations from the blocks in the possession of the Association, which are an integral part of the Report.

4. That the Council be requested to consider a Resolution by the Committee of Section A, recommending that the Reports of the Electrical Standards Committee from 1862 be reprinted, after careful editing, and published as a memorial to the late Lord Kelvin.

Synopsis of Grants of Money appropriated for Scientific Purposes by the General Committee at the Dublin Meeting, September 1908. *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.
*Turner, Professor H. H.—Seismological Observations	60	0	0
*Shaw, Dr. W. N.—Investigation of the Upper Atmosphere by means of Kites	10	0	0
*Preece, Sir W. H.—Magnetic Observations at Falmouth	50	0	0
Gill, Sir David—Establishing a Solar Observatory in Australia	50	0	0

Chemistry.

	£	s.	d.
*Roscoe, Sir H. E.—Wave-length Tables of Spectra	10	0	0
*Divers, Professor E.—Study of Hydro-aromatic Substances	15	0	0
*Armstrong, Professor H. E.—Dynamic Isomerism	35	0	0
*Kipping, Professor F. S.—Transformation of Aromatic Nitro-amines	10	0	0
Kipping, Professor F. S.—Electroanalysis	30	0	0

Geology.

	£	s.	d.
*Tiddeman, R. H.—Erratic Blocks	12	0	0
*Herdman, Professor W. A.—Fauna and Flora of British Trias	8	0	0
*Lamplugh, G. W.—Fossiliferous Drift Deposits	11	0	0
*Harker, Dr. A.—Crystalline Rocks of Anglesey	1	0	0
*Gregory, Professor J. W.—Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
*Lapworth, Professor C.—Palæozoic Rocks of Wales and the West of England	15	0	0
*Watts, Professor W. W.—Composition of Charnwood Rocks	2	0	0
Watts, Professor W. W.—Igneous and Associated Rocks of Glensaul, &c.	20	0	0
Joly, Professor J.—Investigations at Biskra	50	0	0

Zoology.

	£	s.	d.
*Hickson, Professor S. J.—Table at the Zoological Station at Naples	75	0	0
*Woodward, Dr. H.—Index Animalium	75	0	0
*Herdman, Professor W. A.—Hereditary Experiments	10	0	0
Shipley, Dr. A. E.—Feeding Habits of British Birds	5	0	0
Carried forward	£564	0	0

* Reappointed.

	£	s.	d.
Brought forward	564	0	0
Geography.			
*Murray, Sir John—Investigations in the Indian Ocean	35	0	0
*Murray, Sir John—Rainfall and Lake and River Discharge	10	0	0
Economic Science and Statistics.			
*Palgrave, R. H. Inglis—Gold Coinage in Circulation in the United Kingdom	6	0	0
Cannan, Professor E.—Amount and Distribution of Income below the Income-tax Exemption Limit	15	0	0
Engineering.			
Preece, Sir W. H.—Gaseous Explosions	75	0	0
Anthropology.			
*Munro, Dr. R.—Lake Village in the neighbourhood of Glastonbury	5	0	0
*Myres, Professor J. L.—Excavations on Roman Sites in Britain	5	0	0
*Read, C. H.—Age of Stone Circles	30	0	0
*Read, C. H.—Anthropological Notes and Queries	40	0	0
*Hogarth, D. G.—Researches in Crete	70	0	0
Physiology.			
*Schäfer, Professor E. A.—The Ductless Glands	35	0	0
*Sherrington, Professor C. S.—Body Metabolism in Cancer	20	0	0
*Waller, Dr. A. D.—Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
*Hickson, Professor S. J.—Table at the Zoological Station at Naples	25	0	0
Waller, Dr. A. D.—Reflex Muscular Rhythm	10	0	0
Waller, Professor A. D.—Anæsthetics	25	0	0
Starling, Professor E. H.—Tissue Metabolism	20	0	0
Sherrington, Professor C. S.—Mental and Muscular Fatigue	40	0	0
Botany.			
*Scott, Dr. D. H.—Structure of Fossil Plants	5	0	0
*Oliver, Professor F. W.—Botanical Photographs	10	0	0
Darwin, Dr. F.—Experimental Study of Heredity	30	0	0
Blackman, Dr. F. F.—Symbiosis between Turbellarian Worms and Algæ	10	0	0
Johnson, Professor T.—Survey of Clare Island	65	0	0
Carried forward	£1160	0	0

* Reappointed.

	£	s.	d.
Brought forward..	1160	0	0
Education.			
*Magnus, Sir P.—Studies suitable for Elementary Schools ...	5	0	0
*Lodge, Sir Oliver.—Curricula of Secondary Schools	5	0	0
Corresponding Societies Committee.			
*Whitaker, W.—For Preparation of Report	21	0	0
Total	£1191	0	0

* Reappointed.

Annual Meetings, 1909, 1910, *and* 1911.

The Annual Meeting of the Association in 1909 will be held at Winnipeg, Canada, commencing August 25 ; in 1910 at Sheffield, and in 1911 at Portsmouth.

PRESIDENT'S ADDRESS.

ADDRESS

BY

FRANCIS DARWIN, M.A., PH.D., LL.D., F.R.S.,

PRESIDENT.

BEFORE entering on the subject of my Address, I may be allowed to refer to the loss which the British Association has sustained in the death of Lord Kelvin. He joined the Association in 1847, and had been for more than fifty years a familiar figure at our meetings. This is not the occasion to speak of his work in the world or of what he was to his friends, but rather of his influence on those who were personally unknown to him. It seems to me characteristic of him that something of his vigour and of his personal charm was felt far beyond the circle of his intimate associates, and many men and women who never exchanged a word with Lord Kelvin, and are in outer darkness as to his researches, will miss his genial presence and feel themselves the poorer to-day. By the death of Sir John Evans the Association is deprived of another faithful friend. He presided at Toronto in 1897, and since he joined the Association in 1861 had been a regular attendant at our meetings. The absence of his cheerful personality and the loss of his wise counsels will be widely felt.

May I be permitted one other digression before I come to my subject? There has not been a Botanical President of the British Association since the Norwich meeting forty years ago, when Sir Joseph Hooker was in the chair, and in 'eloquent and felicitous words' (to quote my father's letter) spoke in defence of the doctrine of evolution. I am sure that every member of this Association will be glad to be reminded that Sir Joseph Hooker is, happily, still working at the subject that his lifelong labours have so greatly advanced, and of which he has long been recognised as the honoured chief and leader.

You will perhaps expect me to give a retrospect of the progress of evolution during the fifty years that have elapsed since July 1, 1858, when the doctrine of the origin of species by means of natural selection was made known to the world in the words of Mr. Darwin and Mr. Wallace. This would be a gigantic task, for which I am quite unfitted. It seems to me, moreover, that the first duty of your President is to speak on matters to which his own researches have contributed. My work—such as it is—deals with the movements of plants, and it is with this subject that I shall begin. I want to give you a general idea of how the changes going on in the environment act as stimuli and compel plants to execute certain movements. Then I shall show that what is true of those temporary changes of shape we describe as movements is also true of the permanent alterations known as morphological.

I shall insist that, if the study of movement includes the problem of stimulus and reaction, morphological change must be investigated from the same point of view. In fact, that these two departments of inquiry must be classed together, and this, as we shall see, has some important results—namely, that the dim beginnings of habit or unconscious memory that we find in the movements of plants and animals must find a place in morphology; and inasmuch as a striking instance of correlated morphological changes is to be found in the development of the adult from the ovum, I shall take this ontogenetic series and attempt to show you that here also something equivalent to memory or habit reigns.

Many attempts have been made to connect in this way the phenomena of memory and inheritance, and I shall ask you to listen to one more such attempt, even though I am forced to appear as a champion of what some of you consider a lost cause—the doctrine of the inheritance of acquired characters.

Movement.

In his book on 'The Power of Movement in Plants' (1880)[1] my father wrote that 'it is impossible not to be struck with the resemblance between the foregoing movements of plants and many of the actions performed unconsciously by the lower animals.' In the previous year Sachs[2] had in like manner called attention to the essential resemblance between the irritability of plants and animals. I give these statements first because of their simplicity and directness; but it must not be forgotten that before this Pfeffer[3] had begun to lay down the principles of what is now known as *Reizphysiologie*, or the physiology of stimulus, for which he and his pupils have done so much.

The words of Darwin which I have quoted afford an example of the way in which science returns to the obvious. Here we find revived, in a rational form, the point of view of the child or of the writer of fairy stories. We do not go so far as the child; we know that flowers do not talk or walk; but the fact that plants must be classed with animals as regards their manner of reaction to stimuli has now become almost a

[1] P. 571. [2] *Arbeiten*, ii. 1879, p. 282.
[3] *Osmotische Untersuchungen*, 1877, p. 202.

commonplace of physiology. And inasmuch as we ourselves are animals, this conception gives us a certain insight into the reactions of plants which we should not otherwise possess. This is, I allow, a very dangerous tendency, leading to anthropomorphism, one of the seven deadly sins of science. Nevertheless, it is one that must be used unless the great mass of knowledge accumulated by psychologists is to be forbidden ground to the physiologist.

Jennings [1] has admirably expressed the point of view from which we ought to deal with the behaviour of the simpler organisms. He points out that we must study their movements in a strictly objective manner: that the same point of view must be applied to man, and that any resemblances between the two sets of phenomena are not only an allowable but a necessary aid to research.

What, then, are the essential characters of stimuli and of the reactions which they call forth in living organisms? Pfeffer has stated this in the most objective way. An organism is a machine which can be set going by touching a spring or trigger of some kind; a machine in which energy can be set free by some kind of releasing mechanism. Here we have a model of at least some of the features of reaction to stimulation.

The energy of the cause is generally out of all proportion to the effect, *i.e.*, a small stimulus produces a big reaction. The specific character of the result depends on the structure of the machine rather than on the character of the stimulus. The trigger of a gun may be pulled in a variety of different ways without affecting the character of the explosion. Just in the same way a plant may be made to curve by altering its angle to the vertical, by lateral illumination, by chemical agency, and so forth; the curvature is of the same nature in all cases, the release-action differs. One of those chains of wooden bricks in which each knocks over the next may be set in action by a touch, by throwing a ball, by an erring dog, in short by anything that upsets the equilibrium of brick No. 1; but the really important part of the game, the way in which the wave of falling bricks passes like a prairie fire round a group of Noah's Ark animals, or by a bridge over its own dead body and returns to the starting-point, &c.—these are the result of the magnificent structure of the thing as a whole, and the upset of brick No. 1 seems a small thing in comparison.

For myself I see no reason why the term *stimulus* should not be used in relation to the action of mechanisms in general; but by a convention which it is well to respect, *stimulation* is confined to the protoplasmic machinery of living organisms.

The want of proportion between the stimulus and the reply, or, as it has been expressed, the unexpectedness of the result of a given stimulus, is a striking feature in the phenomena of reaction. That this should be so need not surprise us. We can, as a rule, only know the stimulus and

[1] *The Behavior of the Lower Organisms*, 1904, p. 124.

the response, while the intermediate processes of the mechanism are hidden in the secret life of protoplasm. We might, however, have guessed that big changes would result from small stimuli, since it is clear that the success of an organism in the world must depend partly at least on its being highly sensitive to changes in its surroundings. This is the adaptive side of the fundamental fact that living protoplasm is a highly unstable body. Here I may say one word about the adaptation as treated in the *Origin of Species.* It is the present fashion to minimise or deny altogether the importance of natural selection. I do not propose to enter into this subject; I am convinced that the inherent strength of the doctrine will insure its final victory over the present anti-Darwinian stream of criticism. From the Darwinian point of view it would be a remarkable fact if the reactions of organisms to natural stimuli were not adaptive. That they should be so, as they undoubtedly are, is not surprising. But just now I only call attention to the adaptive character of reactions from a descriptive point of view.

Hitherto I have implied the existence of a general character in stimulation without actually naming it; I mean the indirectness of the result. This is the point of view of Dutrochet, who in 1824 said that the environment suggests but does not directly cause the reaction. It is not easy to make clear in a few words the conception of indirectness. Pfeffer[1] employs the word *induction*, and holds that external stimuli act by producing internal change, such changes being the link between stimulus and reaction. It may seem, at first sight, that we do not gain much by this supposition; but since these changes may be more or less enduring, we gain at least the conception of *after effect* as a quality of stimulation. What are known as *spontaneous* actions must be considered as due to internal changes of unknown origin.

It may be said that in speaking of the 'indirectness' of the response to stimuli we are merely expressing in other words the conception of release-action; that the explosion of a machine is an indirect reply to the touch on the trigger. This is doubtless true, but we possibly lose something if we attempt to compress the whole problem into the truism that the organism behaves as it does because it has a certain structure. The quality of indirectness is far more characteristic of an organism than of a machine, and to keep it in mind is more illuminating than a slavish adherence to the analogy of a machine. The reaction of an organism depends on its past history; but, it may be answered, this is also true of a machine the action of which depends on how it was made, and in a less degree on the treatment it has received during use. But in living things this last feature in behaviour is far more striking, and in the higher organisms past experience is all-important in deciding the response to stimulus. The organism is a plastic machine profoundly affected in structure by its own action, and the unknown process intervening between

[1] *Physiology*, Engl. edit., i. p. 11.

stimulus and reaction (on which the indirectness of the response depends) must have the fullest value allowed it as a characteristic of living creatures.

For the zoological side of biology a view similar to that of Pfeffer has been clearly stated by Jennings [1] in his admirable studies on the behaviour of infusoria, rotifers, &c. He advances strong arguments against the theories of Loeb and others, according to which the stimulus acts directly on the organs of movement; a point of view which was formerly held by botanists, but has since given place to the conception of the stimulation acting on the organism as a whole. Unfortunately for botanists these movements are by the zoologists called *tropisms*, and are thus liable to be confused with the geotropism, heliotropism, &c., of plants: to these movements, which are not considered by botanists to be due to direct action of stimuli, Loeb's assumptions do not seem to be applicable.

Jennings's position is that we must take into consideration what he calls 'physiological state, *i.e.*, "the varying internal physiological conditions of the organism, as distinguished from permanent anatomical conditions."' Though he does not claim novelty for his view, I am not aware that it has ever been so well stated. External stimuli are supposed to act by altering this physiological state; that is, the organism is temporarily transformed into what, judged by its reactions, is practically a different creature.

This may be illustrated by the behaviour of *Stentor*, one of the fixed infusoria.[2] If a fine jet of water is directed against the disc of the creature, it contracts 'like a flash' into its tube. In about half a minute it expands again and the cilia resume their activity. Now we cause the current to act again upon the disc. This time the *Stentor* does not contract, which proves that the animal has been in some way changed by the first stimulus. This is a simple example of 'physiological state.' When the *Stentor* was at rest, before it received the first current of water, it was in state 1, the stimulus changed state 1 into state 2, to which contraction is the reaction. When again stimulated it passed into state 3, which does not produce contraction.

We cannot prove that the contraction which occurred when the *Stentor* was first stimulated was due to a change of state. But it is a fair deduction from the result of the whole experiment, for after the original reaction the creature is undoubtedly in a changed state, since it no longer reacts in the same way to a repetition of the original stimulus.

Jennings points out that, as in the case of plants, spontaneous acts are brought about when the physiological state is changed by unknown causes, whereas in other cases we can point to an external agency by which the same result is effected.

[1] H. S. Jennings, *Contributions to the Study of the Behavior of the Lower Organisms*. Carnegie Institution, 1904, p. 111.

[2] Jennings, *Behavior of the Lower Organisms*, 1906, p. 170.

Morphological Changes.

Let us pass on to the consideration of the permanent or morphological changes and the stimuli by which they are produced, a subject to which, in recent years, many workers have devoted themselves. I need only mention the names of Vöchting, Goebel, and Klebs among botanists, and those of Loeb, Herbst, and Driesch among zoologists, to remind you of the type of research to which I refer.

These morphological alterations produced by changes in environment have been brought under the rubric of reaction to stimulation, and must be considered as essentially similar to the class of temporary movements of which I have spoken.

The very first stage in development may be determined by a purely external stimulus. Thus the position of the first cell-wall in the developing spore of *Equisetum* is determined by the direction of incident light.[1] In the same way the direction of light settles the plane of symmetry of *Marchantia* as it develops from the gemma.[2] But the more interesting cases are those where the presence or absence of a stimulus makes an elaborate structural difference in the organism. Thus, as Stahl[3] has shown, beech leaves developed in the deep shade of the middle of the tree are so different in structure from leaves grown in full sunlight that they would unhesitatingly be described as belonging to different species. Another well-known case is the development of the scale-leaves on the rhizome of *Circæa* into the foliage leaves under the action of light.[4]

The power which the experimenter has over the lower plants is shown by Klebs, who kept *Saprolegnia mixta*, a fungus found on dead flies, in uninterrupted vegetative growth for six years; while by removing a fragment of the plant and cultivating it in other conditions the reproductive organs could at any time be made to appear.[5]

Chlamydomonas media, a unicellular green alga, when grown in a 0·4 per cent. nutrient solution continues to increase by simple division, but conjugating gametes are formed in a few days if the plant is placed in pure water and kept in bright light.[6] Numberless other cases could be given of the regulation of form in the lower organisms. Thus *Sporodinia* grown on peptone-gelatine produces sporangiferous hypha, but on sugar zygotes are formed. Again, *Protosiphon botryoides*, if grown on damp clay, can most readily be made to produce spores by tranference to water either in light or in darkness. But for the same plant cultivated in Knop's solution the end can best be obtained by placing the culture in the dark.[7] Still these instances of the regulation of reproduction are not so interesting from our point of view as some of Klebs' later results.[8] Thus he has shown that the colour of the flower of *Campanula trachelium*

[1] Stahl, *Ber. d. Bot. Ges.*, 1885, p. 334.
[2] Pfeffer, in Sachs' *Arbeiten*, i. p. 92.
[3] *Jenaische Zeitschr.*, 1883, p. 162.
[4] Goebel in *Bot. Zeitung*, 1880.
[5] *Willkürliche Entwick.*, p. 27.
[6] Klebs, *Bedingungen*, 1896, p. 430.
[7] *Biol. Centralbl.* 1904, pp. 451–3.
[8] *Jahrb. f. wiss. Bot.*, xlii. 1906, p. 162.

can be changed from blue to white and back again to blue by varying the conditions under which the plant is cultivated. Again, with *Sempervivum*[1] he has been able to produce striking results—*e.g.*, the formation of apetalous flowers with one instead of two rows of stamens. Diminution in the number of stamens is a common occurrence in his experimental plants, and absolute loss of these organs also occurs. Many other abnormalities were induced, both in the stamens and in other parts of the flowers.

There is nothing new in the character of these facts;[2] what has been brought to light (principally by the work of Klebs) is the *degree* to which ontogeny is controllable. We are so much in the habit of thinking of the stable element in ontogeny that the work of Klebs strikes us with something of a shock. Most people would allow that change of form is ultimately referable to changed conditions, but many of us were not prepared to learn the great importance of external stimuli in ontogeny.

Klebs begins by assuming that every species has a definite *specific structure*, which he compares to chemical character. Just as a substance such as sulphur may assume different forms under different treatment, so he assumes that the specific structure of a plant has certain potentialities which may be brought to light by appropriate stimuli. He divides the agencies affecting the structure into external and internal conditions, the external being supposed to act by causing alterations in the internal conditions.

It will be seen that the scheme is broadly the same as that of Pfeffer for the case of the movement and other temporary reactions. The internal conditions of Klebs correspond also to the 'physiological state' of Jennings.

From what has gone before, it will be seen that the current conception of stimulus[3] is practically identical whether we look at the

[1] *Abhandl. Naturforsch. Ges. zu Halle*, xxv., 1906, pp. 31, 34, &c.

[2] See the great collection of facts illustrating the 'direct and definite action of the external conditions of life' in *Variation of Animals and Plants*, ii. 271.

[3] With regard to the terminology of stimulation, I believe that it would greatly simplify matters if our classification of causal conditions could be based on the relation of the nucleus to the rest of the cell. But our knowledge does not at present allow of more than a tentative statement of such a scheme. It is now widely believed that the nucleus is the bearer of the qualities transmitted from generation to generation, and the regulator of ontogeny. May we not therefore consider it probable that the nucleus plays in the cell the part of a central nervous system? In plants there is evidence that the ectoplasm is the sensitive region, and, in fact, plays the part of the cell's sense-organ. The change that occurs in the growth of a cell, as a response to stimulus, would on this scheme be a reflex action dependent for its character on the structure of the nucleus. The 'indirectness' of stimulation would then depend on the reception by the nucleus of the excitation set up in the ectoplasm, and the secondary excitation reflected from the nucleus, leading to certain changes in the growth of the cell.

If the nucleus be the bearer of the past history of the individual, the scheme here sketched would accord with the adaptive character of normal reactions and would phenomena of movement or those of structure. If this is allowable—and the weight of evidence is strongly in its favour—a conclusion of some interest follows.

If we reconsider what I have called the indirectness of stimulation, we shall see that it has a wider bearing than is at first obvious. The 'internal condition' or 'physiological state' is a factor in the regulation of the organism's action, and it is a factor which owes its character to external agencies which may no longer exist.

The fact that stimuli are not momentary in effect but leave a trace of themselves on the organism is in fact the physical basis of the phenomena grouped under memory in its widest sense as indicating that action is regulated by past experience. Jennings[1] remarks: 'In the higher animals, and especially in man, the essential features in behaviour depend very largely on the history of the individual; in other words, upon the present physiological condition of the individual, as determined by the stimuli it has received and the reactions it has performed. But in this respect the higher animals do not differ in principle, but only in degree, from the lower organisms. . . .' I venture to believe that this is true of plants as well as of animals, and that it is further broadly true not only of physiological behaviour, but of the changes that are classed as morphological.

Semon in his interesting book, *Die Mneme*,[2] has used the word *Engram* for the trace or record of a stimulus left on the organism. In this sense we may say that the internal conditions of Pfeffer, the physiological states of Jennings, and the internal conditions of Klebs are, broadly speaking, *Engrams*. The authors of these theories may perhaps object to this sweeping statement, but I venture to think it is broadly true.

The fact that in some cases we recognise the chemical or physical character of the internal conditions does not by any means prevent our ascribing a *mnemic* memory-like character to them, since they remain causal agencies built up by external conditions which have, or may have, ceased to exist. Memory will be none the less memory when we know something of the chemistry and physics of its neural concomitant.

fall into line with what we know of the regulation of actions in the higher organisms. Pfeffer (*Physiology of Plants*, Eng. trans., iii. 10) has briefly discussed the possibility of thus considering the nucleus as a reflex centre, and has pointed out difficulties in the way of accepting such a view as universally holding good. Delage (*L'Hérédité*, 2nd edit., 1903, p. 88) gives a good summary of the evidence which induces him to deny the mastery of the cell by the nucleus. Driesch, however (*Analytische Theorie der organischen Entwicklung*, 1894, p. 81), gives reasons for believing that the cytoplasm is the receptive region, while the nucleus is responsible for the reaction, and it is on this that he bases his earlier theory of ontogeny.

[1] P. 124 (1904).

[2] *Die Mneme, als erhaltendes Prinzip im Wechsel des organischen Geschehens*, von Richard Semon, 1te Auflage, Leipzig 1904, 2te Auflage, 1908. It is a pleasure to express my indebtedness to this work, as well as for the suggestions and criticisms which I owe to Professor Semon personally.

Habit illustrated by Movement.

In order to make my meaning plain as to the existence of a *mnemic* factor in the life of plants, I shall for the moment leave the morphological side of life and give an instance of habitual movement.

Sleeping plants are those in which the leaves assume at night a position markedly different from that shown by day. Thus the leaflets of the scarlet-runner (*Phaseolus*) are more or less horizontal by day and sink down at night. This change of position is known to be produced by the alternation of day and night. But this statement by no means exhausts the interest of the phenomenon. A sensitive photographic plate behaves differently in light and darkness; and so does a radiometer, which spins by day and rests at night.

If a sleeping-plant is placed in a dark room after it has gone to sleep at night, it will be found next morning in the light-position, and will again assume the nocturnal position as evening comes on. We have, in fact, what seems to be a habit built by the alternation of day and night. The plant normally drops its leaves at the stimulus of darkness and raises them at the stimulus of light. But here we see the leaves rising and falling in the absence of the accustomed stimulation. Since this change of position is not due to external conditions it must be the result of the internal conditions which habitually accompany the movement. This is the characteristic *par excellence* of habit—namely, a capacity, acquired by repetition, of reacting to a fraction of the original environment. We may express it in simpler language. When a series of actions are compelled to follow each other by applying a series of stimuli they become organically tied together, or *associated*, and follow each other automatically, even when the whole series of stimuli are not acting. Thus in the formation of habit *post hoc* comes to be equivalent to *propter hoc*. Action B automatically follows action A, because it has repeatedly been compelled to follow it.

This may be compared with Herbert Spencer's[1] description of an imaginary case, that of a simple aquatic animal which contracts its tentacles on their being touched by a fish or a bit of seaweed washed against it. If such a creature is also sensitive to light the circumstances under which contraction takes place will be made up of two stimuli—those of light and of contact—following each other in rapid succession. And, according to the above statement of the essential character of associative habit, it will result that the light-stimulus alone may suffice, and the animal will contract without being touched.

Jennings[2] has shown that the basis of memory by association exists in so low an organism as the infusorian *Stentor*. When the animal is stimulated by a jet of water containing carmine in suspension, a physiological state A is produced, which, however, does not immediately lead to a visible

[1] *Psychology*, 2nd edit., 1870, vol. i. p. 435.

[2] *Behavior of the Lower Organisms*, 1906, p. 289.

reaction. As the carmine stimulus is continued or repeated, state B is produced, to which the *Stentor* reacts by bending to one side. After several repetitions of the stimulus, state C is produced, to which the animal responds by reversing its ciliary movement, and C finally passes into D, which results in the *Stentor* contracting into its tube. The important thing is that after many repetitions of the above treatment the organism 'contracts at once as soon as the carmine comes in contact with it.' In other words, states B and C are apparently omitted, and A passes directly into D, *i.e.*, into the state which gives contraction as a reaction. Thus we have in an infusorian a case of short-circuiting precisely like the case which has been quoted from Herbert Spencer as illustrating association. But Jennings' case has the advantage of being based on actual observation. He generalises the result as the 'law of the resolution of physiological states' in the following words: 'The resolution of one physiological state into another becomes easier and more rapid after it has taken place a number of times.' He goes on to point out that the operation of this law is seen in the higher organisms, 'in the phenomena which we commonly call memory, association, habit-formation, and learning.'

In spite of this evidence of mnemic power in the simplest of organisms, objections will no doubt be made to the statement that association of engrams can occur in plants.

Pfeffer, whose authority none can question, accounts for the behaviour of sleeping plants principally on the more general ground that when any movement occurs in a plant there is a tendency for it to be followed by a reversal—a swing of the physiological pendulum in the other direction. Pfeffer[1] compares it to a released spring which makes several alternate movements before it settles down to equilibrium. But the fact that the return movements occur at the same time-intervals as the stimuli is obviously the striking feature of the case. If the pendulum-like swing always tended to occur naturally in a twelve hours' rhythm it would be a different matter. But Pfeffer has shown that a rhythm of six hours can equally well be built up. And the experiments of Miss Pertz and myself[2] show that a half-hourly or quarter-hourly rhythm can be produced by alternate geotropic stimulation.

We are indebted to Keeble[3] for an interesting case of apparent habit among the lower animals. *Convoluta roscoffensis*, a minute wormlike creature found on the coast of Brittany, leads a life dependent on the ebb and flow of the sea. When the tide is out the *Convoluta* come to the surface, showing themselves in large green patches. As the rising tide begins to cover them they sink down into safer quarters. The remarkable fact is that when kept in an aquarium, and therefore removed from tidal

[1] See Pfeffer, *Abhandl. K. Sächs. Ges.*, Bd. xxx. 1907. It is impossible to do justice to Pfeffer's point of view in the above brief statement.

[2] *Annals of Botany*, 1892 and 1903.

[3] Gamble and Keeble, *Q. J. Mic. Science*, xlvii. p. 401.

action, they continue for a short time to perform rhythmic movements in time with the tide.

Let us take a human habit, for instance that of a man who goes a walk every day and turns back at a given mile-post. This becomes habitual, so that he reverses his walk automatically when the limit is reached. It is no explanation of the fact that the stimulus which makes him start from home includes his return—that he has a mental return-ticket. Such explanation does not account for the point at which he turns, which as a matter of fact is the result of association. In the same way a man who goes to sleep will ultimately wake; but the fact that he wakes at four in the morning depends on a habit built up by his being compelled to rise daily at that time. Even those who will deny that anything like association can occur in plants cannot deny that in the continuance of the nyctitropic rhythm in constant conditions we have, in plants, something which has general character of habit, *i.e.*, a rhythmic action depending on a rhythmic stimulus that has ceased to exist.

On the other hand, many will object that even the simplest form of association implies a nervous system. With regard to this objection it must be remembered that plants have two at least of the qualities characteristic of animals—namely, extreme sensitiveness to certain agencies and the power of transmitting stimuli from one part to another of the plant body. It is true that there is no central nervous system, nothing but a complex system of nuclei; but these have some of the qualities of nerve cells, while intercommunicating protoplasmic threads may play the part of nerves. Spencer[1] bases the power of association on the fact that every discharge conveyed by a nerve 'leaves it in a state for conveying a subsequent like discharge with less resistance.' Is it not possible that the same thing may be as true of plants as it apparently is of infusoria? We have seen reasons to suppose that the 'internal conditions' or 'physiological states' in plants are of the nature of engrams, or residual effects of external stimuli, and such engrams may become associated in the same way.

There is likely to be another objection to my assumption that a simple form of associated action occurs in plants—namely, that association implies consciousness. It is impossible to know whether or not plants are conscious; but it is consistent with the doctrine of continuity that in all living things there is something psychic, and if we accept this point of view we must believe that in plants there exists a faint copy of what we know as consciousness in ourselves.[2]

I am told by psychologists that I must define my point of view. I am accused of occupying that unscientific position known as 'sitting on the fence.' It is said that, like other biologists, I try to pick out what suits my purpose from two opposite schools of thought—the psychological and the physiological.

[1] *Psychology*, 2nd edit., vol. i. p. 615.

[2] See James Ward, *Naturalism and Agnosticism*, vol. i., Lecture X.

What I claim is that, as regards reaction to environment, a plant and a man must be placed in the same great class, in spite of the obvious fact that as regards complexity of behaviour the difference between them is enormous. I am not a psychologist, and I am not bound to give an opinion as to how far the occurrence of definite actions in response to stimulus is a physiological and how far a psychological problem. I am told that I have no right to assume the neural series of changes to be the cause of the psychological series, though I am allowed to say that neural changes are the universal concomitants of psychological change. This seems to me, in my ignorance, an unsatisfactory position. I find myself obliged to believe that the mnemic quality in all living things (which is proved to exist by direct experiment) must depend on the physical changes in protoplasm, and that it is therefore permissible to use these changes as a notation in which the phenomena of habit may be expressed.

Habit illustrated by Morphology.

We have hitherto been considering the mnemic quality of movements; but, as I have attempted to show, morphological changes are reactions to stimulation of the same kind as these temporary changes. It is indeed from the morphological reactions of living things that the most striking cases of habit are, in my opinion, to be found.

The development of the individual from the germ-cell takes place by a series of stages of cell-division and growth, each stage apparently serving as a stimulus to the next, each unit following its predecessor like the movements linked together in an habitual action performed by an animal.

My view is that the rhythm of ontogeny is actually and literally a habit. It undoubtedly has the feature which I have described as pre-eminently characteristic of habit, viz., an automatic quality which is seen in the performance of a series of actions in the absence of the complete series of stimuli to which they (the stages of ontogeny) were originally due. This is the chief point on which I wish to insist—I mean that the resemblance between ontogeny and habit is not merely superficial, but deeply seated. It was with this conclusion in view that I dwelt, at the risk of being tedious, on the fact that memory has its place in the morphological as well as in the temporary reactions of living things. It cannot be denied that the ontogenetic rhythm has the two qualities observable in habit—namely, a certain degree of fixity or automaticity, and also a certain variability. A habit is not irrevocably fixed, but may be altered in various ways. Parts of it may be forgotten or new links may be added to it. In ontogeny the fixity is especially observable in the earlier, the variability in the later, stages. Mr. Darwin has pointed out that 'on the view that species are only strongly marked and fixed varieties, we might expect often to find them still continuing to vary in those parts of their structure which have varied within a moderately recent period.' These remarks are in explanation of the 'notorious' fact that specific are more variable than generic characters—a fact for which it is 'almost superfluous to adduce evidence.' [1] This, again, is what we find in habit: take the case of a man who, from his youth up, has daily repeated a certain form of words. If in middle life an addition is made to the formula, he will find the recently acquired part more liable to vary than the rest.

Again, there is the wonderful fact that, as the ovum develops into the perfect organism, it passes through a series of changes which are believed to represent the successive forms through which its ancestors passed in the process of evolution. This is precisely paralleled by our own experience of memory, for it often happens that we cannot reproduce the last learned verse of a poem without repeating the earlier part; each verse is suggested by the previous one and acts as a stimulus for the next. The blurred and imperfect character of the ontogenetic version of the phylogenetic series may at least remind us of the tendency to abbreviate by omission what we have learned by heart.

In all bi-sexual organisms the ontogenetic rhythm of the offspring is a combination of the rhythms of its parents. This may or may not be visible in the offspring; thus in the crossing of two varieties the mongrel assumes the character of the prepotent parent. Or the offspring may show a blend of both parental characters. Semon [2] uses as a model the two versions of Goethe's poem—

'Ueber allen Gipfeln, ist Ruh, in allen $\left\{\begin{array}{l}\text{Wäldern, hörest du, keinen Hauch.'}\\ \text{Wipfeln, spürest du, kaum einen Hauch.'}\end{array}\right.$

One of these terminations will generally be prepotent, probably the one that was heard first or heard most often. But the cause of such prepotency may be as obscure as the corresponding occurrence in the formation of mongrels. We can only say that in some persons the word 'allen' releases the word 'Wäldern,' while in others it leads up to 'Wipfeln.' Again, a mixture of the terminations may occur leading to such a mongrel form as: 'in allen Wäldern hörest du kaum einen Hauch.' The same thing is true of music; a man with an imperfect memory easily interpolates in a melody a bar that belongs elsewhere. In the case of memory the introduction of a link from one mental rhythm into another can only occur when the two series are closely similar, and this may remind us of the difficulty of making a cross between distantly related forms.

Enough has been said to show that there is a resemblance between the two rhythms of development and of memory; and that there is at least a *prima facie* case for believing them to be essentially similar. It will be seen that my view is the same as that of Hering, which is generally described as the identification of memory and inheritance.[3]

[1] *Origin of Species*, 6th edit., p. 122.

[2] *Die Mneme*, 2nd edit., pp. 147, 221, 303, 345.

[3] Everyone who deals with this subject must take his stand on the foundation laid by Hering in his celebrated address given at Vienna in 1870 and reprinted in No. 148 of Ostwald's *Exakt Klassiker*. The passage quoted (p. 16) is from Samuel

Hering says that 'between the *me* of to-day and the *me* of yesterday lie night and sleep, abysses of unconsciousness; nor is there any bridge but memory with which to span them.' And in the same way he claims that the abyss between two generations is bridged by the unconscious memory that resides in the germ cells. It is also the same as that of Semon and to a great extent as that of Rignano.[1] I, however, prefer at the moment to limit myself to asserting the identity of ontogeny and habit, or, more generally, to the assertion in Semon's phraseology, that ontogeny is a mnemic phenomenon.

Evolution, in its modern sense, depends on a change in the ontogenetic rhythm. This is obvious, since if this rhythm is absolutely fixed, a species can never give rise to varieties. This being so, we have to ask *in what ways* the ontogenetic rhythm can be altered. An habitual action, for instance, a trick learned by a dog, may be altered by adding new accomplishments; at first the animal will persist in finishing his performance at the old place, but at last the extended trick will be bonded into a rhythm of actions as fixed as was the original simpler performance. May we not believe that this is what has occurred in evolution?

We know from experiment that a plant may be altered in form by causes acting on it during the progress of development. Thus a beech tree may be made to develop different forms of leaves by exposing it to sunshine or to shade. The ontogeny is different in the two cases, and what is of special interest is, that there exist shade-loving plants in which a structure similar to that of the shaded beech-leaf is apparently typical of the species, but on this point it is necessary to speak with caution. In the same way Goebel points out that in some orchids the assimilating roots take on a flattened form when exposed to sunlight, but in others this morphological change has become automatic, and occurs even in darkness.[2]

Such cases suggest at least the possibility of varieties arising as changes in or additions to the later stages of ontogeny. This is, briefly given, the epigenetic point of view.

But there is another way of looking at the matter—namely, that upheld by Galton and Weismann. According to this view ontogeny can only be changed by a fundamental upset of the whole system—namely, by an alteration occurring in its first stage, the germ cell, and this view is now very generally accepted.

The same type of change may conceivably occur in memory or habit: that is, the rhythm as a whole may be altered by some cause acting on the nerve-centres connected with the earlier links of the series. The

Butler's translation of Hering in *Unconscious Memory*, 1880, p. 110. Butler had previously elaborated the view that 'we are one person with our ancestors' in his entertaining book *Life and Habit*, 1878, and this was written in ignorance of Hering's views.

[1] *Sur la transmissibilité des caractères acquis*, Paris, 1906.

[2] Goebel's *Organography of Plants*, part ii. p. 285.

analogy is not exact, but such an imaginary case is at least of a different type from a change in habit consisting in the addition of a new link or the alteration of one of the latest formed links. If we were as ignorant of the growth of human actions as we are of variation, we might have a school of naturalists asserting that all changes in habit originate in the earliest link of the series. But we know that this is not the case. On the other hand, I fully admit that the structure of an ovum may in this way be altered, and give rise to a variation which may be the starting-point of a new species.

But how can a new species originate according to an epigenetic theory? How can a change in the latter stages of ontogeny produce a permanent alteration in the germ-cells? Our answer to this question will depend on our views of the structure of the germ-cells. According to the mnemic theory they have the quality which is found in the highest perfection in nerve-cells, but is at the same time a character of all living matter—namely, the power of retaining the residual effects of former stimuli and of giving forth or reproducing under certain conditions an echo of the original stimulus. In Semon's phraseology germ-cells must, like nerve-cells, contain engrams, and these engrams must be (like nerve-engrams) bonded together by association, so that they come into action one after another in a certain order automatically, *i.e.*, in the absence of the original stimuli.

This seems to me the strength of the mnemic theory—namely, that it accounts for the preformed character of germ-cells by the building up in them of an organised series of engrams. But if this view has its strength, it has also its weakness. Routine can only be built up by repetition, but each stage in ontogeny occurs only once in a lifetime. Therefore if ontogeny is a routine each generation must be mnemically connected with the next. This can only be possible if the germ-cells are, as it were, in telegraphic communication with the whole body of the organism; so that as ontogeny is changed by the addition of new characters, new engrams are added to the germ-cell.

Thus in fact the mnemic theory of development depends on the possibility of what is known as somatic inheritance or the inheritance of acquired characters. This is obvious to all those familiar with the subject, but to others it may not be so clear. Somatic inheritance is popularly interesting in relation to the possible inherited effects of education, or of mutilations, or of the effects of use and disuse. It is forgotten that it may be, as I have tried to show, an integral part of all evolutionary development.

Weismann's Theory.

Everyone must allow that if Weismann's theory of inheritance is accepted we cannot admit the possibility of somatic inheritance. This may be made clear to those unfamiliar with the subject by an illustration taken from the economy of an ant's nest or beehive. The queen[1] on

[1] Nor do the drones share the activity of the workers.

whom depends the future of the race is cut off from all active experience of life: she is a mere reproducing machine, housed, fed, and protected by the workers. But these, on whom falls the burden of the struggle for life and the experience of the world generally, are sterile, and take no direct share in the reproduction of the species. The queen represents Weismann's germ-plasm, the workers are the body or soma. Now imagine the colony exposed to some injurious change in environment; the salvation of the species will depend on whether or no an improved pattern of worker can be produced. This depends on the occurrence of appropriate variations, so that the queen bee and the drones, on whom this depends, are of central importance. On the other hand any change occurring in the workers—for instance, increased skill due to practice in doing their work or changes in their structure due to external conditions—cannot possibly be inherited, since workers are absolutely cut off from the reproduction of the race. According to Weismann, there is precisely the same bar to the inheritance of somatic change.

The racial or phyletic life of all organisms is conceived by him as a series of germ-cells whose activity is limited to varying, and whose survival in any generation depends on the production of a successful soma or body capable of housing, protecting, and feeding the germ-cell. Most people would *a priori* declare that a community where experience and action are separated must fail. But the bee's nest, which must be allowed to be something more than an illustration of Weismann's theory, proves the contrary.

It is clear that there must be war to the knife between the theory of Weismann and that of the somatists—to coin a name for those who believe in the inheritance of acquired characters. A few illustrations may be given of the strength of Weismann's position. Some trick or trivial habit appears in two successive generations, and the son is said to inherit it from his father. But this is not necessarily a case of somatic inheritance, since according to Weismann the germ-plasm of both father and son contained the potentiality of the habit in question. If we keep constantly in view Weismann's theory of continuity, the facts which are supposed to prove somatic inheritance cease to be decisive.

Weismann has also shown by means of his hypothesis of 'simultaneous stimulation'[1] the unconvincingness of a certain type of experiment. Thus Fischer showed that when chrysalids of *Arctia caja* are subjected to low temperature a certain number of them produce dark-coloured insects; and further that these moths mated together yield dark-coloured offspring. This has been held to prove somatic inheritance, but Weismann points out that it is explicable by the low temperature having an identical effect on the colour-determinants existing in the wing-rudiments of the pupa, and on the same determinants occurring in the germ-cells.

It does not seem to me worth while to go in detail into the evi-

[1] I borrow this convenient expression from Plate's excellent book, *Ueber die Bedeutung des Darwin'schen Selectionsprincips*, 1903, p. 81.

dence by which somatists strive to prove their point, because I do not know of any facts which are really decisive. That is to say, that though they are explicable as due to somatic inheritance, they never seem to me absolutely inexplicable on Weismann's hypothesis. But, as already pointed out, it is not necessary to look for special facts and experiments, since if the mnemic theory of ontogeny is accepted the development of every organism in the world depends on somatic inheritance.

I fully acknowledge the strength of Weismann's position ; I acknowledge also most fully that it requires a stronger man than myself to meet that trained and well-tried fighter. Nevertheless, I shall venture on a few remarks. It must be remembered that, as Romanes[1] pointed out, Weismann has greatly strengthened his theory of heredity by giving up the absolute stability and perpetual continuity of germ-plasm. Germ plasm is no longer that mysterious entity, immortal and self-contained, which used to suggest a physical soul. It is no longer the aristocrat it was when its only activity was dependent on its protozoan ancestors, when it reigned absolutely aloof from its contemporary subjects. The germ-plasm theory of to-day is liberalised, though it is not so democratic as its brother sovereign Pangenesis, who reigns, or used to reign, by an elaborate system of proportional representation. But in spite of the skill and energy devoted to its improvement by its distinguished author, Weismannism fails, in my opinion, to be a satisfactory theory of evolution.

All such theories must account for two things which are parts of a single process but may logically be considered separately : (i) The fact of ontogeny, namely, that the ovum has the capacity of developing into a certain more or less predetermined form ; (ii) The fact of heredity—the circumstance that this form is approximately the same as that of the parent.

The doctrine of pangenesis accounts for heredity, since the germ-cells are imagined as made up of gemmules representing all parts of the adult ; but it does not account for ontogeny, because there seems to me no sufficient reason why the gemmules should become active in a predetermined order unless, indeed, we allow that they do so by habit, and then the doctrine of pangenesis becomes a variant of the mnemic theory.

The strength of Weismann's theory lies in its explanation of heredity. According to the doctrine of continuity, a fragment of the germ-plasm is, as it were, put on one side and saved up to make the germ-cell of the new generation, so that the germ-cells of two successive generations are made of the same material. This again depends on Weismann's belief that when the ovum divides, the two daughter cells are not identical ; that in fact the fundamental difference between soma and germ-cells begins at this point. But this is precisely where many naturalists whose observations are worthy of all respect differ from him. Weismann's theory is therefore threatened at the very foundation.

[1] *An Examination of Weismann*, 1893, pp. 169, 170.

Even if we allow Weismann's method of providing for the identity between the germ-cell of two successive generations, there remains, as above indicated, a greater problem—namely, that of ontogeny. We no longer look at the potentiality of a germ-cell as Caliban looked on Setebos, as something essentially incomprehensible ruling the future in an unknown way—'just choosing so.' If the modern germ-cell is to have a poetic analogue it must be compared to a Pandora's box of architectonic sprites which are let loose in definite order, each serving as a master builder for a prescribed stage of ontogeny. Weismann's view of the mechanism by which his determinants—the architectonic sprites—come into action in due order is, I assume, satisfactory to many, but I confess that I find it difficult to grasp. The orderly distribution of determinants depends primarily on their arrangement in the ids, where they are held together by 'vital affinities.' They are guided to the cells on which they are to act by differential divisions, in each of which the determinants are sorted into two unequal lots. They then become active, *i.e.*, break up into biophores, partly under the influence of liberating stimuli and partly by an automatic process. Finally the biophores communicate a 'definite vital force' to the appropriate cells.[1] This *may* be a description of what happens; but inasmuch as it fails to connect the process of ontogeny with physiological processes of which we have definite knowledge, it does not to me seem a convincing explanation.

For myself I can only say that I am not satisfied with Weismann's theory of heredity or of ontogeny. As regards the first, I incline to deny the distinction between germ and soma, to insist on the plain facts that the soma is continuous with the germ-cell, and that the somatic cells may have the same reproductive qualities as the germ-cells (as is proved by the facts of regeneration); that, in fact, the germ-cell is merely a specialised somatic cell and has the essential qualities of the soma. With regard to ontogeny, I have already pointed out that Weismann does not seem to explain its automatic character.

The Mnemic Theory.

If the mnemic theory is compared with Weismann's views it is clear that it is strong precisely where these are weakest—namely, in giving a coherent theory of the rhythm of development. It also bears comparison with all theories in which the conception of determinants occurs. Why should we make elaborate theories of hypothetical determinants to account for the potentialities lying hidden in the germ-cell, and neglect the only determinants of whose existence we have positive knowledge (though we do not know their precise nature)? We know positively that by making a dog sit up and then giving him a biscuit we build up something in his brain in consequence of which a biscuit becomes the stimulus to the act of sitting. The mnemic theory assumes that the

[1] *The Evolution Theory*, Eng. trans., i. 373 *et seq.*

determinants of morphological change are of the same type as the structural alteration wrought in the dog's brain.

The mnemic theory—at any rate that form of it held by Semon and by myself—agrees with the current view, viz., that the nucleus is the centre of development, or, in Semon's phraseology, that the nucleus contains the engrams in which lies the secret of the ontogenetic rhythm. But the mode of action of the mnemic nucleus is completely different from that of Weismann. He assumes that the nucleus is disintegrated in the course of development by the dropping from it of the determinants which regulate the manner of growth of successive groups of cells. But if the potentiality of the germ nucleus depends on the presence of engrams, if, in fact, its function is comparable to that of a nerve-centre, its capacity is not diminished by action; it does not cast out engrams from its substance as Weismann's nucleus is assumed to drop armies of determinants. The engrams are but cut deeper into the records, and more closely bonded one with the next. The nucleus, considered as a machine, does not lose its component parts in the course of use. We shall see later on that the nuclei of the whole body may, on the mnemic theory, be believed to become alike. The fact that the mnemic theory allows the nucleus to retain its repeating or reproductive or mnemic quality supplies the element of continuity. The germ-cell divides and its daughter cells form the tissues of the embryo, and in this process the original nucleus has given rise to a group of nuclei; these, however, have not lost their engrams, but retain the potentiality of the parent nucleus. We need not therefore postulate the special form of continuity which is characteristic of Weismann's theory.

We may say, therefore, that the mnemic hypothesis harmonises with the facts of heredity and ontogeny. But the real difficulties remain to be considered, and these, I confess, are of a terrifying magnitude.

The first difficulty is the question how the changes arising in the soma are, so to speak, telegraphed to the germ-cells. Hering allows that such communication must at first seem highly mysterious.[1] He then proceeds to show how by the essential unity and yet extreme ramification of the nervous system 'all parts of the body are so connected that what happens in one echoes through the rest, so that from the disturbance occurring in any part some notification, faint though it may be, is conveyed to the most distant parts of the body.'

A similar explanation is given by Nägeli. He supposes that adaptive, in contradistinction to organic, characters are produced by external causes; and since these characters are hereditary there must be communication between the seat of adaptation and the germ-cells. This telegraphic effect is supposed to be effected by the network of idioplasm which traverses the body, in the case of plants by the intercellular protoplasmic threads.

[1] E. Hering in Ostwald's *Klassiker der exakten Wissenschaften*, No. 148, p. 14; see also S. Butler's translation in *Unconscious Memory*, p. 119.

Semon faces the difficulty boldly. When a new character appears in the body of an organism, in response to changing environment, Semon assumes that a new engram is added to the nuclei in the part affected; and that, further, the disturbance tends to spread to all the nuclei of the body (including those of the germ-cells), and to produce in them the same change. In plants the flow must be conceived as travelling by intercellular plasmic threads, but in animals primarily by nerve-trunks. Thus the reproductive elements must be considered as having in some degree the character of nerve-cells. So that, for instance, if we are to believe that an individual habit may be inherited and appear as an instinct, the repetition of the habit will not merely mean changes in the central nervous system, but also corresponding changes in the germ-cells. These will be, according to Semon, excessively faint in comparison to the nerve-engrams, and can only be made efficient by prolonged action. Semon lays great stress on the slowness of the process of building up efficient engrams in the germ-cells.

Weismann [1] speaks of the impossibility of germinal engrams being formed in this way. He objects that nerve-currents can only differ from each other in intensity, and therefore there can be no communication of potentialities to the germ-cell. He holds it to be impossible that somatic changes should be telegraphed to the germ-cell and be reproduced ontogenetically—a process which he compares to a telegram despatched in German and arriving in Chinese. According to Semon [2] what radiates from the point of stimulation in the soma is the primary excitation set up in the somatic cells; if this is so, the radiating influence will produce the same effect on all the nuclei of the organism. My own point of view is the following. In a plant (as already pointed out) the ectoplasm may be compared to the sense-organ of the cell, and the primary excitation of the cell will be a change in the ectoplasm; but since cells are connected by ectoplasmic threads the primary excitation will spread and produce in other cells a faint copy of the engram impressed on the somatic cells originally stimulated. But in all these assumptions we are met by the question to which Weismann has called attention—namely, whether nervous impulses can differ from one another in *quality*? [3] The general opinion of physiologists is undoubtedly to the opposite effect—namely, that all nervous impulses are identical in quality. But there are notable exceptions: for instance, Hering, [4] who strongly

[1] Weismann, *The Evolution Theory*, 1904, vol. ii. p. 63; also his *Richard Semon's 'Mneme' und die Vererbung erworbener Eigenschaften*, in the *Archiv für Rassen- und Gesellschafts-Biologie*, 1906. Semon has replied in the same journal for 1907.

[2] Semon, *Mneme*, ed. i. p. 142, does not, however, consider it proved that the nucleus is necessarily the smallest element in which the whole inheritance resides. He refers especially to the regeneration of sections of *Stentor* which contain mere fragments of the nucleus.

[3] I use this word in the ordinary sense without reference to what is known as *modality*.

[4] *Zur Theorie der Nerventhätigkeit, Akademische Vortrag*, 1898 (Veit, Leipzig).

supports what may be called the qualitative theory. I am not competent to form an opinion on the subject, but I confess to being impressed by Hering's argument that the nerve-cell and nerve-fibre, as parts of one individual (the neuron), must have a common irritability. On the other hand there is striking evidence, in Langley's [1] experiments on the cross-grafting of efferent nerves, that here at least nerve impulses are interchangeable and therefore identical in quality. The state of knowledge as regards afferent nerves is, however, more favourable to my point of view. For the difficulties that meet the physiologist—especially as regards the nerves of smell and hearing—are so great that it has been found simpler to assume differences in impulse-quality, rather than attempt an explanation of the facts on the other hypothesis.[2]

On the whole it may be said that, although the trend of physiological opinion is against the general existence of qualitative differences in nerve-impulses, yet the question cannot be said to be settled either one way or the other.

Another obvious difficulty is to imagine how within a single cell the engrams or potentialities of a number of actions can be locked up. We can only answer that the nucleus is admittedly very complex in structure. It may be added (but this not an answer) that in this respect it claims no more than its neighbours; it need not be more complex than Weismann's germ-plasm. One conceivable simplification seems to be in the direction of the pangenes of De Vries. He imagines that these heritage units are relatively small in number, and that they produce complex results by combination, not by each being responsible for a minute fraction of the total result.[3] They may be compared to the letters of the alphabet which by combination make an infinity of words.[4] Nägeli [5] held a similar view. 'To understand heredity,' he wrote, 'we do not need a special independent symbol for every difference conditioned by space, time, or quality, but a substance which can represent every possible combination of differences by the fitting together of a limited number of elements, and which can be transformed by permutations into other combinations.' He applied (*loc. cit.*, p. 59) the idea of a combination of symbols to the telegraphic quality of his idioplasm. He suggests that as the nerves convey the most varied perceptions of external objects to the central nervous system, and there create a coherent picture, so it is not impossible that the idioplasm may convey a combination of its local alterations to other parts of the organism.

Another theory of simplified telegraphy between soma and germ-cell

[1] *Proc. R. Soc.*, 1904, p. 99. *Journal of Physiology*, xxiii. p. 240, and xxxi. p. 365.

[2] See Nagel, *Handbuch der Physiologie des Menschen*, iii. (1905), pp. 1–15.

[3] De Vries, *Intracellular Pangenesis*, p. 7.

[4] I take this comparison from Lotsy's account of De Vries' theory. Lotsy, *Vorlesungen über Deszendenztheorien*, 1906, i. p. 98.

[5] Nägeli's *Abstammungslehre*, 1884, p. 73.

is given by Rignano.[1] I regret that the space at my command does not permit me to give a full account of his interesting speculation on somatic inheritance. It resembles the theories of Hering, Butler, and Semon in postulating a quality of living things, which is the basis both of memory and inheritance. But it differs from them in seeking for a physical explanation or model of what is common to the two. He compares the nucleus to an electric accumulator which in its discharge gives out the same sort of energy that it has received. How far this is an allowable parallel I am not prepared to say, and in what follows I have given Rignano's results in biological terms. What interests me is the conclusion that the impulse conveyed to the nucleus of the germ-cell is, as far as results are concerned, the external stimulus. Thus, if a somatic cell (A) is induced by an external stimulus (S) acting on the nucleus to assume a new manner of development, a disturbance spreads through the organism, so that finally the nuclei of the germ-cells are altered in a similar manner. When the cellular descendants of the germ-cells reach the same stage of ontogeny as that in which the original stimulation occurred, a stimulus comes into action equivalent to S as regards the results it is capable of producing. So that the change originally wrought in cell A by the actual stimulus S is now reproduced by what may be called an inherited stimulus. But when A was originally affected other cells, B, C, D, may have reacted to S by various forms of growth. And therefore when during the development of the altered germ-cell something equivalent to S comes into play, there will be induced, not merely the original change in the development of A, but also the changes which were originally induced in the growth of B, C, D. Thus, according to Rignano, the germ-nucleus releases a number of developmental processes, each of which would, according to Weismann, require a separate determinant.

If the view here given is accepted, we must take a new view of Weismann's cases of *simultaneous stimulation*, i.e., cases like Fischer's experiments on *Arctia caja*, which he does not allow to be somatic inheritance. If we are right in saying that, the original excitation of the soma is transferred to the germ-cell, and it does not matter whether the stimulus is transferred by 'telegraphy,' or whether a given cause, *e.g.*, a low temperature, acts simultaneously on soma and germ-cell. In both cases we have a given alteration produced in the nuclei of the soma and the germ-cell. Nägeli used the word *telegraphy* to mean a dynamic form of transference, but he did not exclude the possibility of the same effect being produced by the movement of chemical substances, and went so far as to suggest that the sieve tubes might convey such stimuli in plants. In any case this point of view[2] deserves careful consideration.

[1] For what is here given I am partly indebted to Signor Rignano's letters.

[2] See Semon, *Archiv f. Rassen- und Gesellschafts-Biologie*, 1907, p. 39.

Still another code of communication seems to me to be at least conceivable. One of the most obvious characteristics of animal life is the guidance of the organism by certain groups of stimuli, producing either a movement of seeking (positive reaction[1]) or one of avoidance (negative reaction). Taking the latter as being the simplest, we find that in the lowest as in the highest organisms a given reaction follows each one of a number of diverse conditions which have nothing in common save that they are broadly harmful in character. We withdraw our hands from a heated body, a prick, a corrosive substance, or an electric shock. The interesting point is that it is left to the organism to discover by the method of trial and error the best means of dealing with a sub-injurious stimulus. May we not therefore say that the existence of pleasure and pain simplifies inheritance? It certainly renders unnecessary a great deal of detailed inheritance. The innumerable appropriate movements performed by animals are broadly the same as those of their parents, but they are not necessarily inherited in every detail; they are rather the unavoidable outcome of hereditary but unspecialised sensitiveness. It is as though heredity were arranged on a code-system instead of by separate signals for every movement of the organism.

It may be said that in individual life the penalty of failure is pain, but that the penalty for failure in ontogenetic morphology is death. But it is only because pain is the shadow cast by Death as he approaches that it is of value to the organism. Death would be still the penalty of creatures that had not acquired this sensitiveness to the edge of danger. Is it not possible that the sensitiveness to external agencies by which structural ontogeny is undoubtedly guided may have a similar quality, and that morphological variations may also be reactions to the edge of danger. But this is a point of view I cannot now enter upon.

It may be objected that the inheritance of anything so complex as an instinct is difficult to conceive on the mnemic theory. Yet it is impossible to avoid suspecting that at least some instincts originate in individual acquirements, since they are continuous with habits gained in the lifetime of the organism. Thus the tendency to peck at any small object is undoubtedly inherited; the power of distinguishing suitable from unsuitable objects is gained by experience. It may be said that the engrams concerned in the pecking instinct cannot conceivably be transferred from the central nervous system to the nucleus of the germ-cells. To this I might answer that this is not more inconceivable than Weismann's assumption that the germ-cell chances to be so altered that the young chicken pecks instinctively. Let us consider another case of what appears to be an hereditary movement. Take, for instance, the case of a young dog, who in fighting bites his own lips. The pain thus produced will induce him to tuck up his lips out of harm's way. This protective movement will become firmly associated with, not only the act of fighting,

[1] See Jennings, *Behavior of the Lower Organisms.*

but with the remembrance of it, and will show itself in the familiar snarl of the angry dog. This movement is now, I presume, hereditary in dogs, and is so strongly inherited by ourselves (from simian ancestors) that a lifting of the corner of the upper lip is a recognised signal of adverse feeling. Is it really conceivable that the original snarl is due to that unspecialised stimulus we call pain, whereas the inherited snarl is due to fortuitous upsets of the determinants in the germ-cell?

I am well aware that many other objections may be advanced against the views I advocate. To take a single instance, there are many cases where we should expect somatic inheritance, but where we look in vain for it. This difficulty, and others equally important, must for the present be passed over. Nor shall I say anything more as to the possible means of communication between the soma and the germ-cells. To me it seems conceivable that some such telegraphy is possible. But I shall hardly wonder if a majority of my hearers decide that the available evidence in its favour is both weak and fantastic. Nor can I wonder that, apart from the problem of mechanism, the existence of somatic inheritance is denied for want of evidence. But I must once more insist that, according to the mnemic hypothesis, somatic inheritance lies at the root of all evolution. Life is a gigantic experiment which the opposing schools interpret in opposite ways. I hope that in this dispute both sides will seek out and welcome decisive results. My own conviction in favour of somatic inheritance rests primarily on the automatic element in ontogeny. It seems to me certain that in development we have an actual instance of habit. If this is so, somatic inheritance must be a *vera causa*. Nor does it seem impossible that memory should rule the plasmic link which connects successive generations—the true miracle of the camel passing through the eye of a needle—since, as I have tried to show, the reactions of living things to their surroundings exhibit in the plainest way the universal presence of a mnemic factor.

We may fix our eyes on phylogeny and regard the living world as a great chain of forms, each of which has learned something of which its predecessors were ignorant; or we may attend rather to ontogeny, where the lessons learned become in part automatic. But we must remember that the distinction between phylogeny and ontogeny is an artificial one, and that routine and acquisition are blended in life.[1]

The great engine of natural selection is taunted nowadays, as it was fifty years ago, with being merely a negative power. I venture to think that the mnemic hypothesis of evolution makes the positive value of natural selection more obvious. If evolution is a process of drilling organisms into habits, the elimination of those that cannot learn is an

[1] This subject is dealt with in a very interesting manner in Professor James Ward's forthcoming lectures on the *Realm of Ends*. Also in his article on *Mechanism and Morals* in the *Hibbert Journal*, October 1905, p. 92; and in his article on Psychology in the *Encyclopædia Britannica*, 1886, vol. xx. p. 44.

integral part of the process, and is no less real because it is carried out by a self-acting system. It is surely a positive gain to the harmony of the universe that the discordant strings should break. But natural selection does more than this ; and just as a trainer insists on his performing dogs accommodating themselves to conditions of increasing complexity, so does natural selection pass on its pupils from one set of conditions to other and more elaborate tests, insisting that they shall endlessly repeat what they have learned and forcing them to learn something new. Natural selection attains in a blind, mechanical way the ends gained by a human breeder ; and by an extension of the same metaphor it may be said to have the power of a trainer—of an automatic master with endless patience and all time at his disposal.

REPORTS

ON THE

STATE OF SCIENCE.

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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*), 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* Messrs. G. MATTHEY, A. P. TROTTER, T. MATHER, *and* F. E. SMITH.

THE Committee desire in the first place to record their deep sense of the loss they have sustained by the death of Lord Kelvin. He was an original member of the Committee appointed at Cambridge, October 3, 1862, and he continued his active interest in their work up to the end. His name will always be associated with the establishment of the absolute system of electrical measurement and with the determination of the absolute units. The Reports of the Committee from 1862 onwards contain a large amount of valuable information in a form which is not generally very accessible—the reprint of the earlier reports, issued under the editorship of Fleeming Jenkin in 1873, is out of print—and the Committee suggest that their reports from 1862 up to the present time might be reprinted as a memorial to Lord Kelvin. The present time is in other respects specially suitable for such a reissue, for it is hoped that the proposed International Congress, to be held in London in October, will settle in a definite manner the few matters relating to the fundamental units which are still outstanding, and will organise a method whereby a close agreement may be maintained among the electrical standards in use throughout the world.

The electrical measurements of certain of the fundamental units, which have been in progress for some time at the National Physical Laboratory, have been brought to a conclusion, and the results published in three papers in the 'Philosophical Transactions' of the Royal Society.

1. 'A New Current Weigher and a Determination of the Electromotive Force of the Normal Weston Cadmium Cell.' By Professor W. E. Ayrton, F.R.S., and T. Mather, F.R.S., Central Technical College, London; and F. E. Smith, A.R.C.Sc., National Physical Laboratory, Teddington, *Phil. Trans.*, A, vol. 207, pp. 463–549.

2. 'On the Normal Weston Cadmium Cell.' By F. E. Smith, *Phil. Trans.*, A, vol. 207, pp. 393–420.

3. 'On a Comparison of many forms of Silver Voltameters.' By F. E. Smith; and 'A Determination of the Electrochemical Equivalent of Silver.' By F. E. Smith and T. Mather, F.R.S., *Phil. Trans.*, A, vol. 207, pp. 545–581.

'The Chemistry of the Silver Voltameter.' By F. E. Smith and T. M. Lowry, D.Sc., *Phil. Trans.*, A, vol. 207, pp. 581–599.

From the first of these it appears that to a very high degree of accuracy the electromotive force of the Weston cadmium cell, as set up at the National Physical Laboratory, when expressed in terms of the ampere (10^{-1} C.G.S. units of current) and the international ohm is $1{\cdot}0183_0$ at a temperature of 17° C.

The second Paper deals with the preparation of the Weston cadmium cell, and contains a comparison between cells set up at the Laboratory and others constructed elsewhere, the general conclusion being that cells can be prepared by different persons in different countries which will agree in E.M.F. to 1 or 2 parts in 100,000.

In the third Paper there is given an account of a comparison of some six forms of silver voltameters, and it is shown that the silver deposited by a current of one ampere in all these various forms is the same if proper precautions are taken, and amounts to

1·11827 milligramme per second.

After this work was completed a comparison was made by Messrs. T. Mather and F. E. Smith, by the kindness of Mr. Trotter, between the ampere standard of the Board of Trade and the ampere as realised by the new Ayrton Jones balance at the National Physical Laboratory. The comparison, an account of which appears in the 'Proceedings of the Royal Society,' A, vol. 80, 1908, was very satisfactory.

It was found that the Board of Trade ampere will deposit silver at the rate of $1{\cdot}1179_1$ milligramme per second, a value which is nearly identical with the number $1{\cdot}1179_4$ given by Lord Rayleigh and Mrs. Sidgwick in 1884. Indirectly the E.M.F. of the normal Weston cadmium cell was found to be $1{\cdot}0187_9$ Board of Trade volts at 17° C., the Board of Trade volt being defined as the potential difference between the terminals of a resistance of 1 Board of Trade ohm when 1 Board of Trade ampere is passing through it.

During the year the ten mercury standards at the National Physical Laboratory have again been set up and intercompared. An account of this work appears in an Appendix by Mr. F. E. Smith, the value of the international ohm, as realised by the mean of the ten tubes, being taken as unit. The following table gives the values of the individual tubes as found in 1903 and 1907 :—

Mercury Standard	Value in Mean International Ohms		Difference value 1907–1903
	1903	1907	
M	$0{\cdot}97170_5$	$0{\cdot}97169_9$	-0_6
P	$1{\cdot}00038_7$	$1{\cdot}00042_1$	$+3_4$
T	$1{\cdot}00019_5$	$1{\cdot}00020_6$	$+1_1$
U	$0{\cdot}97349_7$	$0{\cdot}97348_8$	-0_9
V	$1{\cdot}00137_9$	$1{\cdot}00137_1$	-0_8
X	$1{\cdot}00106_8$	$1{\cdot}00106_2$	-0_6
Y	$1{\cdot}00026_7$	$1{\cdot}00026_5$	-0_2
Z	$1{\cdot}00130_6$	$1{\cdot}00129_9$	-0_7
G	$1{\cdot}00105_2$	$1{\cdot}00104_4$	-0_8
S	$1{\cdot}00097_4$	$1{\cdot}00097_2$	-0_2

Except in the case of Tube P, where there is an apparent change of 3 to 4 parts in 100,000, the differences are negligible.

Mr. Smith has also compared with the mercury tubes a large series of wire standard resistances, including those made by Matthiessen and Hockin for the B. A. Committee in 1865–67, and various other old standards kindly lent to the Committee by their owners for the purpose. The general conclusion is that all the original coils except D and E, which are made of platinum, have changed appreciably since they were constructed, though since 1888, during a period of twenty years, for which the coils have been very carefully watched, the changes also in A, B, C, H, and Flat have been small. F and G have, however, in the same period changed considerably.

Resistance at 16°·0 *in terms of the original B.A. unit* (1867).

Coil	Material	1867	1876	1879–81	1888	1908	Maximum Change
A	Pt. Ir.	1·00000	1·00077	1·00056	1·00147	1·00122	0·00147
B	Pt. Ir.	1·00029	1·00121	1·00080	1·00104	1·00098	0·00092
C	Au. Ag.	1·00050	1·00141	1·00101	1·00146	1·00173	0·00123
D	Pt.	1·00092	1·00092	1·00092	1·00092	1·00092	0·00000
E	Pt.	1·00152	1·00152	1·00152	1·00152	1·00152	0·00000
F	Pt. Ag.	—	—	1·00016	1·00072	1·00160	0·00144
G	Pt. Ag.	1·00022	1·00030	0·99982	1·00025	1·00175	0·00193
H	Pt. Ag.	1·00020	—	—	1·00042	1·00044	0·00024
Flat	Pt. Ag.	—	—	1·00079	1·00120	1·00125	0·00046

The mean resistance of 6 other platinum-silver coils, first measured in 1888, appears to have increased since that time by 14 parts in 100,000; and 5 more platinum-silver coils, first measured in 1894–7, have now a greater mean value by 8 parts in 100,000.

It would appear also that in many of the variable coils the changes have occurred mainly, if not entirely, at the soft-soldered joints, and with a view of testing this the Committee have authorised the Secretary to open and examine one of the coils.

A comparison, given in the Appendix, has also been made of all the manganin resistances in the possession of the Standards Department of the Laboratory. The behaviour of the various coils is somewhat different; while some have been very constant, others appear to have changed considerably.

At the Conference on Electrical Units, held at the Reichsanstalt in 1905, it was suggested that the Jena glass 59''' was, from its good elastic properties, the best glass to employ for mercury resistances, and accordingly efforts have been made to get some suitable tubes. Five tubes of 16''' have recently been secured, after great difficulty, which will probably do for standards. Tubes of 59''' have not yet been obtained: the difficulty of drawing them is a serious obstacle to their use.

A number of tubes of French glass, 'verre dur,' are also on order.

Progress has also been made during the year in the design of the Lorenz apparatus, to be given by the Drapers' Company, and the manufacture of the bed and the heavy-metal work has been entrusted to Messrs. Armstrong, Whitworth & Co., who have kindly undertaken it. The marble cylinders required have been delivered at the National Physical Laboratory.

Preparations for the holding of an International Congress on Electrical Units in London in October next are well advanced.

Specifications dealing with the international ohm, the international ampere, and the Weston cadmium cell, which have been prepared at the National Physical Laboratory after consultation with other workers to serve as a basis of discussion at the Congress, are given in the Appendix with a view of making them known.

The grant of 50*l.* made to the Committee at Leicester has been spent in great part in the purchase of materials for the Weston cells and the silver voltameter research and in obtaining suitable tubes for use for standards of resistance.

The balance now in hand is 1*l.* 0*s.* 4*d.*, and the Committee recommend that they be allowed to retain this for the purpose of continuing the experiments now in progress.

The Committee therefore recommend that their Reports from 1862 onwards be reprinted, after careful editing, as a memorial to Lord Kelvin, and that they be reappointed, with a grant of 100*l.* in addition to the above unexpended balance, for the purpose of undertaking this work and continuing their researches on the standards; that Lord Rayleigh be Chairman and Dr. R. T. Glazebrook Secretary.

APPENDIX I.

On the Secular Changes of the Standards of Resistance at the National Physical Laboratory. *By* F. E. Smith, *A.R.C.Sc.*

(From the National Physical Laboratory.)

It has long been known that many resistance coils of platinum-silver, of manganin, and of other resistance alloys do not keep constant in resistance. The causes of the changes may lie in some alteration in structure of the alloy, of some change in strain, of surface action, of faulty joints, or, as suggested by Dr. Rosa, they may lie in the insulating medium.

The question of the permanence of manganin standards has been discussed recently by Messrs. Rosa and Babcock [1] and by Drs. Jaeger and Lindeck,[2] and it seemed desirable to bring together all the information available regarding the changes which have taken place in the coils of the Association, and of others which have from time to time been compared with them.

At the National Physical Laboratory the primary standards of resistance are of mercury, and the secondary standards are of platinum, platinum-iridium, gold-silver, platinum-silver, and of manganin. It will be shown that the mercury standards have kept constant, that the platinum coils have probably kept constant, that the platinum-iridium, gold-silver, and a few of the platinum-silver coils have changed considerably, while other platinum-silver coils have kept very nearly constant. Of the manganin coils a few have kept very nearly constant, but most of them have increased in resistance.

The platinum, platinum-iridium, and some of the gold-silver and platinum-silver coils are the property of the Association, and many of them were first compared by Matthiessen and Hockin in 1865–7. Most of the manganin standards were constructed by O. Wolff, Berlin, but four were built by Mr. Melsom at the National Physical Laboratory. These standards vary in nominal value from one-thousandth of an ohm to 10,000 ohms.

The method of comparing resistances has been dealt with in a previous Report,[3] and for the purposes of this communication it will be sufficient to state that, on all occasions when mercury standards were erected, the resistance coils were measured in terms of the mean unit represented by the mercury columns, with a probable error of about 5 parts in 1,000,000. In the intervals between the comparisons with mercury standards the values of the coils in international ohms were at times uncertain within 1 to 2 parts in 100,000, but the relative values of the unit coils of manganin with potential leads could at all times be determined with an error not greater than about 2 parts in 10,000,000, and the one-thousandth ohm and 10,000 ohms manganin standards could in general be measured in terms of the unit coils within about 5 parts in 1,000,000. In the intervals between the erections of the mercury tubes a very careful survey of the history of the coils was often necessary to determine the most probable changes in the coils, and a slight readjustment of the values allotted to the coils was sometimes made when the mercury standards were next employed. The probable error of the resistance values assigned to the manganin standards on any date is almost certainly less than 1 part in 100,000.

Mercury Standards of Resistance.

The mercury standards of resistance are 10 in number, and were constructed in 1902–3. The mean international ohm as realised by the ten standards is taken as the unit, and each tube is measured in terms of it.

[1] *The Electrician*, June 14, 1907, and November 15, 1907.
[2] *Ibid.*, August 2, 1907.
[3] *B.A. Report*, Section A, 1906.

In practice two manganin coils act as intermediaries. The measured values in 1903 and 1907 are given in the following table :—

TABLE I.

Giving the Values of the Mercury Standards in 1903 *and* 1907.

Mercury Standard	Value in Mean International Ohms		Difference 1907–1903
	1903	1907	
M	$0·97170_5$	$0·97169_9$	-0_6
P	$1·00038_7$	$1·00042_1$	$+3_4$
T	$1·00019_5$	$1·00020_6$	$+1_1$
U	$0·97349_7$	$0·97348_8$	-0_9
V	$1·00137_9$	$1·00137_1$	-0_8
X	$1·00106_8$	$1·00106_2$	-0_6
Y	$1·00026_7$	$1·00026_5$	-0_2
Z	$1·00130_6$	$1·00129_9$	-0_7
G	$1·00105_2$	$1·00104_4$	-0_8
S	$1·00097_4$	$1·00097_2$	-0_2

With the exception of P the relative values of the standards have kept remarkably constant, and in the case of P the increase in resistance may be apparent only, for only in 1907 has an increase been noted. It is thought that a very thin film of grease may be coating a portion of the inner wall of the tube. As the tubes M, G, and S are of French *verre dur*, and the remainder of Jena 16''' glass, there is justification for assuming the constancy of the standards. It is of interest to state that the relative values of the French mercury standards in 1885 and 1905, and of the mercury standards of the Reichsanstalt in 1893 and 1904, are also in very good agreement.

Wire Standards of Platinum, Platinum-Iridium, Gold-Silver, and Platinum-Silver.

The original coils of the Association are six in number: two are of platinum, two of platinum-iridium, one of gold-silver, and one of platinum-silver. They were compared together by Messrs. Matthiessen and Hockin in 1865–67, by Messrs. Chrystal and Saunder in 1876, by Dr. Fleming in 1879–81, by Dr. Glazebrook and Mr. Fitzpatrick in 1887–88, and by the author in 1908. In addition to these six coils, Messrs. Chrystal and Saunder examined a platinum-silver coil marked No. 29 F, and also a coil known as Flat, while measurements of another platinum-silver coil H are given in the Report for 1888. These coils—in all, 9—have remained in charge of the Secretary.

In a report to the Association in 1888 Dr. Glazebrook discussed the probable changes which had taken place in the coils since 1867, and changes in the platinum-silver coils only are discussed in the Reports for 1892 and 1903. In 1865–67 the probable error of the comparisons appears to have been of that order which would be introduced by an error in the temperature of the coils of about 0°·1 C. In 1888 and 1903 the error of the comparisons corrresponds with an error in the temperature of the coils of a little less than 0°·1 C., and in 1908 the error has been reduced so as to correspond with about 0°·02 C. All of the coils are surrounded by paraffin wax, and it is only by maintaining a constant temperature for many hours that very accurate observations can be made. The scale of temperature employed for the 1908 measurements is the hydrogen scale; that used for previous observations is almost certainly the Kew glass scale. Dr. J. A. Harker has recently shown[1] that the difference between these two scales is negligibly small; hence we may assume that the same scale of temperature has been used throughout.

The present method of comparing the coils is by substitution in one arm of a Wheatstone shunt bridge, of which the other three arms consist of manganin resistances. The high-temperature coefficient coils are kept in a room remaining constant in temperature to 0°·01 C. over several days, and the temperature does not differ from 16°·0 C. by more than 0°·5 C. About 16 measurements, spread over several days, are made of each coil, and the value at 16°·0 C. is deduced from these measurements. During 1908 approximate values for the temperature coefficients of resistance of the coils have been obtained by varying the temperature from 14° to 17° C. These values are given in Tables III. and IX.

In 1867 the temperatures are given at which the coils were 1 B.A. unit, and this procedure was in part followed in 1876, 1879, and 1888. The unit of 1867 was, however, probably different to those of 1876, 1879, and 1888. Messrs. Chrystal and Saunder (1876) assumed one of the coils (B) to have remained constant between 1867 and 1876, and expressed the values of the other coils in terms of it. The unit, in terms of which the measurements of 1879–81 were made, is the mean B.A. unit as indicated by Fleming on his chart; it is supposed to represent the mean of the resistances of the six coils A, B, C, D, E, G at the temperatures at which they were originally correct. It is this unit which was used by Lord Rayleigh in his work on the ohm, and by Dr. Glazebrook since about 1880, and it has been closely adhered to in all measurements made by the Committee since that date.

A close examination of the chart at the present day shows that the mean of the values of the six coils is really about 0·99985 unit; hence if this interpretation be accepted, the mean B.A. unit is really 15 parts in 100,000 less than the unit which has been taken since 1880; but it has not been thought wise to attempt any correction on this score, except in the compilation of Table III. At times a sudden change in a coil has been recorded, as in 1888, when Dr. Glazebrook reported that F had suddenly risen in value by 0·00048 B.A. unit,[2] and that Flat had fallen by 1 part in 10,000.[3] Similar changes may have been observed when the coils were comparatively new, and it is possible that a slightly variable coil was disregarded, or a correction applied because of it, when the chart summarising the observations for 1879–81 was constructed.

The chart gives the values of the coils from 0° C. to 25° C., and the graphs are such that the value of a coil can be read with an error not greater than 3 parts in 100,000, which is equivalent to a change in temperature of 0°·1 C. of a platinum-silver coil. The resistances of the coils at various temperatures as given by the chart are given in Table II.

[1] *Proc. R.S.*, A, vol. 78. [2] *B.A. Report*, 1888.
[3] *Phil. Trans.*, A, 1888, p. 364.

TABLE II.

Giving the Values of the Coils in 1879–81, from Fleming's Chart.

Coil	Temperature at which coil was stated to be correct in 1867	Value of coil, from Fleming's chart, at temperature given in 1867	Value of coil, from Fleming's chart, at 16°·0 C.
A	16°·0 C.	1·00011	1·00011
B	15·8	1·00006	1·00035
C	15·3	1·00007	1 00056
D	15·7	0·99960	1·00052
E	15·7	1·00010	1·00102
F	—	—	0·99971
G	15·2	0·99916	0·99937
Flat	—	—	1·00034

If we tentatively adopt as the B.A. unit at any date the exact mean of the resistances of the coils A, B, C, D, E, G at the temperatures at which they were originally said to be equal, the values of the coils at 16°·0 C. in 1867, 1876, 1879–81, 1888, and 1908 are as given in Table III. This table has been very easy to compile, because only the differences between the resistances of the coils at the various dates, and their temperature coefficients, were required.

In all the tables of this Appendix the values of high-temperature coefficient coils are given within 1 part in 100,000; but as the errors of observation must often have exceeded the change in resistance corresponding with a change in temperature of a coil of 0°·05 to 0°·1 C., too much significance must not be attached to an apparent change in resistance, corresponding with a difference in temperature of a coil of a tenth of a degree.

It is clear that changes of very considerable magnitude have taken

TABLE III.

In this table it is assumed that the B.A. unit is equal to the mean of the coils A, B, C, D, E, G at the temperatures at which they were found by Hockin in 1867 to be correct, and that this mean has not altered.

Values at 16°·0 C.

Coil	Material	Approx. Temperature Coefficient (1908)	1867	1876	1879–81	1888	1892	1903	1908
A	Pt. Ir.	0·00148	1·00000	1·00021	1·00026	1·00083	—	—	1·00034
B	Pt. Ir.	0·00148	1·00029	1·00065	1·00050	1·00040	—	—	1·00010
C	Au. Ag.	0·00070	1·00050	1·00085	1·00071	1·00082	—	—	1·00085
D	Pt.	0·00312	1·00092	1·00036	1·00067	1·00028	—	—	1·00004
E	Pt.	0·00314	1·00091*	1·00099	1·00117	1·00088	—	—	1·00064
F	Pt. Ag.	0·00027	—	—	0·99986	1·00008	1·00051	1·00083	1·00072
G	Pt. Ag.	0·00028	1·00022	0·99974	0·99952	0·99961	0·99925	0·99975	1·00087
H	Pt. Ag.	0·00028	1·00020	—	—	0·99978	0·99943	0·99976	0·99956
Flat	Pt. Ag.	0·00027	—	—	1·00049	1·00056	1·00033	1·00050	1·00037
Mean of A, B, C, D, E, G =			1·00047	1·00047	1·00047	1·00047	—	—	1·00047

* For a note as to this value see p. 39.

place, and the task before us is to select the most constant and the most variable coils. In all such cases a table of difference values is most helpful. Table IV. gives such values for the six coils A, B, C, D, E, G in 1×10^{-5} B.A. units at 16°·0 C.

We conclude from the differences given in column 7 and the temperatures given in the last column of Table IV. that B and E have possibly remained constant during the period 1867–1908 and that C and D are next in order of constancy. The coils D and E have remained relatively constant since 1876.

Dr. Glazebrook in 1888 measured the B.A. unit in terms of the specific resistance of mercury, and found that the value of the resistance of a column of mercury, 1 metre long, 1 sq. mm. in section, at 0° C. was

0·95352 B.A. unit.

For the purposes of the comparison, Dr. Glazebrook used the two coils F and G, and their values are given by him as

F=0·99807 B.A.U. at 10° C.
G=0·99778 „ „ 10° C.

These values were taken from Fleming's chart, and when corrected to 16° C. they are practically identical with those recorded in Table II., as they should be. Flat was also used (0·99857 B.A.U. at 10° C.), but observations during the two years preceding 1888 showed that it was

TABLE IV.

Difference Values in 1×10^{-5} *B.A. Units.*

Coil	1867	1876	1879–81	1888	1908	Maximum Difference between Difference Values	The Difference in Column 7 is equivalent to an Uncertainty of Temperature of the Coil with the Largest Temperature Coefficient of
A – B	–29	–44	–24	43	24	87	0·6 C.
A – C	–50	–64	–45	1	–51	65	0·4
A – D	–92	–15	–41	55	30	147	0·5
A – E	–91	–78	–91	– 5	–30	86	0·3
A – G	–22	47	74	122	–53	175	1·2
B – C	–21	–20	–21	–42	–75	55	0·4
B – D	–63	29	–17	12	6	92	0·3
B – E	–62	–34	–67	–48	–54	33	0·11
B – G	7	91	98	79	–77	175	1·2
C – D	–42	49	4	54	81	123	0·4
C – E	–41	–14	–46	– 6	21	67	0·2
C – G	28	111	119	121	– 2	123	1·8
D – E	1*	–63	–50	–60	–60	64	0·2
D – G	70	62	115	67	–83	198	0·6
E – G	69	125	165	127	–23	188	0·6

* Hockin (1867 Report) gives the temperatures at which D and E were correct in 1865, 1866, and 1867. From the values given by him it appears that the difference D – E was -59×10^{-5} B.A.U. at 16°·0 C. in 1865, -59×10^{-5} in 1866, and 1 in 1867. These differences, taken in conjunction with those given in the above table, make it practically certain that the difference given for 1867 is incorrect, and should be replaced by a difference of the order –60.

relatively lower than when examined by Dr. Fleming, and its value was not, therefore, taken from the chart.

In 1908 the individual coils were compared with the new mercury standards set up at the N.P.L. and their values found in terms of mercury. If we assume that the mean value of the coils A, B, C, D, E, G, is the same as when Fleming's chart was constructed, we obtain as the resistance of 1 metre of mercury, 1 sq. mm. in section, at 0° C., the value

0·95333 B.A.U.,

an alteration of 20 parts in 100,000 since 1888.

If, on the other hand, we suppose that the mercury units set up in 1908 agree exactly with those constructed in 1888, then the mean value of the six coils in question has altered by 0·00020 B.A.U. At the present date, assuming as found in 1888, the resistance of 1 metre of mercury, 1 sq. mm. in section, at 0° C. to be 0·95352 B.A.U., the individual coils have the values given in Table V., column 3.

TABLE V.

Values of Coils at 16°·0 C. in 1888 and 1908 obtained from comparison with Mercury Tubes, assuming the Resistance of 1 Metre of Mercury to be 0·95352 B.A. Unit.

Coil	Value in 1888 at Time of Determination of Specific Resistance of Mercury *	Value in 1908
A	1·00068	1·00042
B	1·00025	1·00018
C	1·00067	1·00093
D	1·00013	1·00012
E	1·00073	1·00072
F	0·99970	1·00080
G	0·99936	1·00095
H	0·99963	0·99964
Flat	1·00023	1·00045

* In Dr. Glazebrook's experiments the terminals of the mercury standards were not exactly at 0° C., and an error of about 4 parts in 100,000 was probably introduced because of this. No correction on this score has, however, been applied, as the magnitude of the error is only of the same order as the probable error of the observations.

The apparent changes in resistance of the coils, together with the alterations in temperature of the coils necessary to produce equal changes in the resistance, are given in Table VI.

TABLE VI.

Coil	Resistance of Coil in 1908 *minus* Resistance of Coil in 1888	Change equivalent to Difference of Temperature of
A	-26×10^{-5} B.A.U.	0·18° C.
B	−7	0·05
C	+26	0·37
D	−1	0·00
E	−1	0·00
F	+110	4·0
G	+159	5·7
H	+1	0·03
Flat	+22	0·81

From Tables V. and VI. it appears to be practically certain that the coils B, D, E, and H have the same resistance in 1908 as they had in 1888. The agreement of the values for D and E is very remarkable, for the temperatures at which these coils were believed to be correct in 1888 are stated to the nearest tenth of a degree only; an apparent change in resistance of 15 parts in 100,000 would, therefore, have been negligible. With respect to G, it has risen by over 1 part in 1,000 during the past 5 years and Flat changed by 17 parts in 100,000 in 1902.[1] The fluctuations in the value of H are believed to have amounted to about 1 part in 10,000 during the period 1888–1908.[2]

Of the four coils B, D, E, H, apparently constant for the period 1888–1908, we have already concluded from the differences given in Table IV. that B, D, and E have remained approximately constant since 1867. One of the coils D–E, appears, from Table IV., to have changed in the interval 1867–1876, and the apparent change corresponds with the change resulting when one of the coils is lowered 0°·2 C. in temperature. It is, however, practically certain that the change is only apparent. The temperatures at which the platinum coils were stated to be correct in 1865, 1866, and 1867 are given by Mr. Hockin in the Report for 1867. They are as follows:

Coil No. 35 (D).	1 B.A U. at	15°·7 C.	January	7, 1865
	1 " "	15°·7 C.	August	18, 1866
	1 " "	15°·7 C.	February	10, 1867
Coil No. 36 (E).	1 " "	15°·5 C.	January	7, 1865
	1 " "	15°·5 C.	August	18, 1866
	1 " "	15°·7 C.	February	10, 1867

In the Report for 1888 the temperature coefficient of D is given as 0·00308 B.A. Unit, and of E as 0·00302 B.A. Unit. These values agree closely with those given in Table III., and they have been used in the compilation of the following complete list of the difference values (D–E) which now deserves attention:

D–E	=	−59	$\times 10^{-5}$	B.A.U. at 16°·0 C.	Year	1865
"	=	−59	"	" "	"	1866
"	=	1	"	" "	"	1867
"	=	−63	"	" "	"	1876
"	=	−50	"	" "	"	1879–81
"	=	−60	"	" "	"	1888
"	=	−60	"	" "	"	1908

The conclusion is obvious. The original difference between the coils was approximately 60×10^{-5} B.A. unit and has remained constant ever since. There is little doubt that the difference recorded for 1867 is incorrect; it may easily happen that there is a difference of 0°·2 C. between the apparent and true temperatures of a coil embedded in paraffin wax, and such a difference would completely explain the 1867 result.

This conclusion necessitates a revision of the difference values in Table IV. The corrections are easily made, for the differences A–E, B–E, C–E and E–G should be respectively equal to the differences A–D, B–D, &c.

We believe that the two platinum coils have remained constant in resistance since 1867, and that the values in 1867, 1879–81, 1888, and 1908 of these and other coils in terms of the original B.A. unit (1867) are as follows:

[1] *Brit. Assoc. Rep.*, 1903. [2] *Ibid.*

TABLE VII.

Resistances at 16°·0 *C. in terms of the original B.A. Unit* (1867).
(*Values obtained through the two Platinum Coils D, E.*)

Coil	Material	1867	1876	1879–81	1888	1908	Maximum Difference
A	Pt. Ir.	1·00000	1·00077	1·00056	1·00147	1·00122	147×10^{-5} B.A.U.
B	Pt. Ir.	1·00029	1·00121	1·00080	1·00104	1·00098	92 ,,
C	Au. Ag.	1·00050	1·00141	1·00101	1·00146	1·00173	123 ,,
D	Pt.	1·00092	1·00092	1·00092	1·00092	1·00092	0 ,,
E	Pt.	1·00152	1·00152	1·00152	1·00152	1·00152	0 ,,
F	Pt. Ag.	—	—	1·00016	1·00072	1·00160	144 ,,
G	Pt. Ag.	1·00022	1·00030	0·99982	1·00025	1·00175	193 ,,
H	Pt. Ag.	1·00020	—	—	1·00042	1·00044	24 ,,
Flat	Pt. Ag.	—	—	1·00079	1·00120	1·00125	46 ,,

From Tables IV. and VII. it is clear that the maximum number of coils which can have kept constant is two, and if the platinum coils have not remained constant then one only of the other coils can have done so. Since D and E are of pure platinum, and not of an alloy, it is probable that these would change least.

If our conclusions are correct, the results are not only of some value as showing the changes which may take place in the resistance of certain alloys when embedded in paraffin wax, but they are also of value because the coils link together so many determinations of the ohm in absolute measure and of the specific resistance of mercury. It is not convenient to collect the various determinations here, but as an instance of the uses to which the data given in this Appendix might be put we take Lord Rayleigh's and Mrs. Sidgwick's determination in 1881 [1] of the specific resistance of mercury. It was found that 0·95412 B.A. unit was equal in resistance to a column of mercury 100 cm. long, 1 sq. mm. in section, at 0° C. Now in Lord Rayleigh's experiments the terminals of the mercury standards were not at 0° C., but at 5° or 6° C., and it was shown by Dr. Glazebrook [2] in 1888 that an error of about 0·00024 was almost certainly introduced because of this. If we apply a correction of this amount, Lord Rayleigh's value becomes 0·95388 B.A. unit as the resistance of 100 cm. of mercury at 0° C. The coils F and Flat were used in the 1881 determination, and the values of these coils were taken from Fleming's chart. They were therefore :

F = 0·99971 B.A. unit at 16°·0 C. (From Table II.)
Flat = 1·00034 B.A. unit at 16°·0 C. (From Table II.)

From Lord Rayleigh's observations, therefore,

F at 16°·0 C. = 0·99971/0·95388 = 104·805 cm. mercury ; and
Flat at 16°·0 C. = 1·00034/0·95388 = 104·871 cm. mercury.

At the present time (1908)

F at 16°·0 C. = 104·959 cm. mercury ; and
Flat at 16°·0 C. = 104·922 cm. mercury.

Using the 1908 values and the changes in F and Flat, recorded in Table VII., we conclude that in 1881

F at 16°·0 C. was equivalent to 104·808 cm. mercury ; and
Flat at 16°·0 C. was equivalent to 104·874 cm. mercury.

[1] *Phil. Trans.*, vol. 174, p. 173.
[2] *Ibid.*, A, 1888, pp. 375–6.

The difference from the values given by Lord Rayleigh is 3 parts in 100,000, which is less than the probable error of the observations. We conclude, therefore, that the determination of Lord Rayleigh and Mrs. Sidgwick in 1881 is in excellent agreement with that made at the National Physical Laboratory in 1908, and this latter has already been shown to agree with that made by Dr. Glazebrook in 1888.

The following is now a very useful summary. The values of the coils in centimetres of mercury in 1881, 1888, and 1908 are given in Table VIII.

TABLE VIII.

Giving the Values at 16°·0 C. *of certain Coils in cm. of Mercury in* 1881, 1888, *and* 1908 *obtained from comparisons with Mercury Standards.*

Coil	1881 Values deduced from Lord Rayleigh's Determination of the Specific Resistance of Mercury. F and Flat were used; for Relative Values of Coils see Table VII.	1888 Values at time of Dr. Glazebrook's Determination. F, G, and Flat were used; for Relative Values of Coils see Table V.	1908 Values directly Determined through N.P.L. Mercury Standards of Resistance	Maximum Difference
	cm.	cm.	cm.	cm.
A	104·847	104·946	104·918	0·071
B	104·872	104·901	104·893	0·029
C	104·894	104·945	104·972	0·078
D	104·885	104·888	104·887	0·003
E	104·948	104·951	104·950	0·003
F	104·805	104·843	104·959	0·154
G	104·769	104·807	104·974	0·205
H	—	104·836	104·837	0·001
Flat	104·871	104·898	104·922	0·051

The preceding comparison strengthens the conclusions already arrived at respecting the most constant coils. From Table VIII., D and E have apparently kept constant in resistance since 1881, while H appears to have remained constant since 1888.

It is of some importance to note that in 1892 the ratio of the B.A. unit to the ohm was accepted as being

1 ohm = 1·01358 B.A. unit,

this being based on the values

100 cm. mercury = 0·9535 B.A. unit.
106·3 cm. mercury = 1 ohm.

Other Platinum-Silver and Gold-Silver Coils.

In addition to the platinum-silver coils, F, G, H, and Flat, originally constructed to represent the B.A. unit at a particular temperature, there are three other platinum-silver coils, numbered 3715 (Nalder Brothers) and 269 and 270 (Elliott Brothers), made to represent the ohm = 1·01358 B.A. unit. There are also two 10-ohm platinum-silver coils, numbered 288 and 289 (Elliott Brothers). All these coils are the property of the Association, and they were extensively used from 1888 to 1903 for the standardising of other coils. From the results of observations recorded in the Report for 1903 it appears that from 1894 to 1903 Nos. 3715 and

270 remained constant in resistance, and that from 1897 to 1903, 288 and 289 remained constant. In 1903 the N.P.L. mercury standards of resistance were constructed, and since then the mercury standards have been taken as constant, and the resistances of all coils expressed by means of them. The B.A. unit (as obtained from all the platinum-silver coils, taking the values given in 1888 as correct, and applying corrections for estimated changes in the coils) was in 1903 found to be equal to 1/1·01367 international ohm. Accepting this ratio for the time being, the resistances at 16°·0 C. of certain coils, compared in 1888, 1894, 1897, 1903, and 1908, are given in the following table :—

TABLE IX.

Coil	Material of Construction	Approx. Temp. Coefficient	Resistance					Maximum Difference (Parts in 100,000)
			1888	1894	1897	1903	1908	
*3715	Pt. Ag.	0·00030	—	1·00050	—	1·00050	1·00057	7
*269	„	0·00029	—	1·00070	—	1·00089	1·00089	19
*270	„	0·00032	—	1·00006	—	1·00006	1·00003	3
*288	„	0·0030	—	—	10·0060	10·0060	10·0056	4
*289	„	0·0026	—	—	10·0026	10·0026	10·0031	5
64	„	0·00033	0·99976	—	—	—	0·99987	11
19	Au. Ag.	0·00071	0·99923	—	—	—	0·99937	14
68 (H)	Pt. Ag.	0·00029	0·99909	—	—	—	0·99932	23
1 C.F.T.	„	0·00028	0·99927	—	—	—	0·99941	14
34	Au. Ag.	0·00071	0·99980	—	—	—	1·00006	26
3	Pt. Ag.	0·0031	9·9956	—	—	—	9·9963	7
4	„	0·0033	9·9941	—	—	—	9·9964	23
10 C.F.T.	„	0·0030	9·9934	—	—	—	9·9940	6

* The resistances of these coils are given in ohms (1 ohm = 1·01358 B.A.U.). The remaining coils have their resistances given in B.A. units.

For the loan of coil No. 64 we are indebted to Professor Trouton, of University College ; originally this coil was in the possession of Professor Carey Foster. For the loan of the coils numbered 19, 68 (H), 1 C.F.T., 34, 3, 4, and 10 C.F.T. we are indebted to Mr. H. A. Taylor, of Victoria Street, London. We tender our hearty thanks to Professor Trouton and Mr. Taylor. All the coils, excepting 19 and 34, are of platinum-silver ; 19 and 34 are of gold-silver.

In Table IX. maximum differences of the order 1 to 5 parts in 100,000 may probably be neglected if this maximum difference does not occur in the period 1903–1908. In 1903 and 1908 the errors of observation were very small, and a recorded difference of 1 or 2 parts in 100,000 must be taken as indicating a true change in the resistance of a coil. The method of measuring a very small change in resistance will be made clear in the next section on manganin coils.

The most constant coils appear to be 270, 288, 289, 10 C.F.T., 3, and 3715. Of these six resistances two only are unit coils ; the remainder are coils of 10 ohms each. In Table IX. the values of eight unit coils and of five 10-ohm coils are tabulated, and of the latter four have kept nearly constant. This fact is important, as it points to the changes of resistance being largely due to actions at the soft-soldered joints, and not entirely, if at all, to the action of paraffin wax (possibly acid) on platinum-silver. In addition, part of the changes may be due to change in structure of the alloy.

The values at 16°·0 C. of the coils A, B, C, D, E, F, G, H and Flat, in terms of the unit of resistance employed for the purposes of Table IX. are approximately

A	= 1·00050	F	= 1·00088
B	= 1·00026	G	= 1·00103
C	= 1·00101	H	= 0·99972
D	= 1·00020	Flat	= 1·00053
E	= 1·00080		

Manganin Standards of Resistance.

The manganin standards of the National Physical Laboratory are in constant use and have proved of very great value. They not only facilitate electrical measurements, but they bring them to a far higher degree of accuracy than was formerly attainable. Nevertheless, the variations in these resistances have in many cases been a source of trouble, and attempts have been made, and are being continued, to construct standard coils of manganin which shall remain practically constant in resistance.

Since 1903 the manganin standards have been intercompared at least four times every year, and the probable changes have been deduced from occasional comparisons with mercury standards and from tables of difference values, due regard being also paid to the past history of the coils. As an example of the comparisons we take the case of seven 1-ohm coils which were intercompared in January, April, July, and October 1906. The observed differences are given in Table X.

TABLE X.

Coils	Differences in 1×10^{-5} ohm at 17°·0 C.				
	Jan. 1906	April 1906	July 1906	Oct. 1906	Maximum Difference
1690–780	6·82	6·87	7·05	5·93	1·12
1690–2351	2·17	2·35	2·04	1·47	0·88
1690–2483	0·26	0·48	0·26	−0·30	0·78
1690–381	−5·80	−6·05	−5·97	−6·27	0·47
1690–L·17	15·63	13·41	12·69	11·80	3·83
1690–L·18	16·69	16·05	15·54	14·92	1·67

Any one of these differences was not obtained from a single observation, but is the mean of six differences. All possible combinations of the seven coils were taken—21 in all—and the differences observed. From these 21 observations six values resulted for the difference between any two of the coils; it is the mean of these six values which is recorded. The temperature during the observations was very nearly 17°·0 C., and the differences were corrected to 17° C. before taking the mean.

An analysis of the figures given in Table X. indicates that the coils L·17 and L·18 probably changed most during 1906, and that the other five coils changed by amounts less than 3 parts in 1,000,000 from January to July 1906. From July to October the difference 1690–780 changed by an appreciable amount and the differences in the values for July and October, viz.:

1690 – 780	Change	= $1{\cdot}12 \times 10^{-5}$ ohm.
1690 – 2351	„	= −0·57 „
1690 – 2483	„	= −0·56 „
1690 – 381	„	= −0·30 „

indicate that 1690 probably fell in resistance in this period by about 6 parts in 1,000,000, and 780 rose by about 5 parts in 1,000,000. The

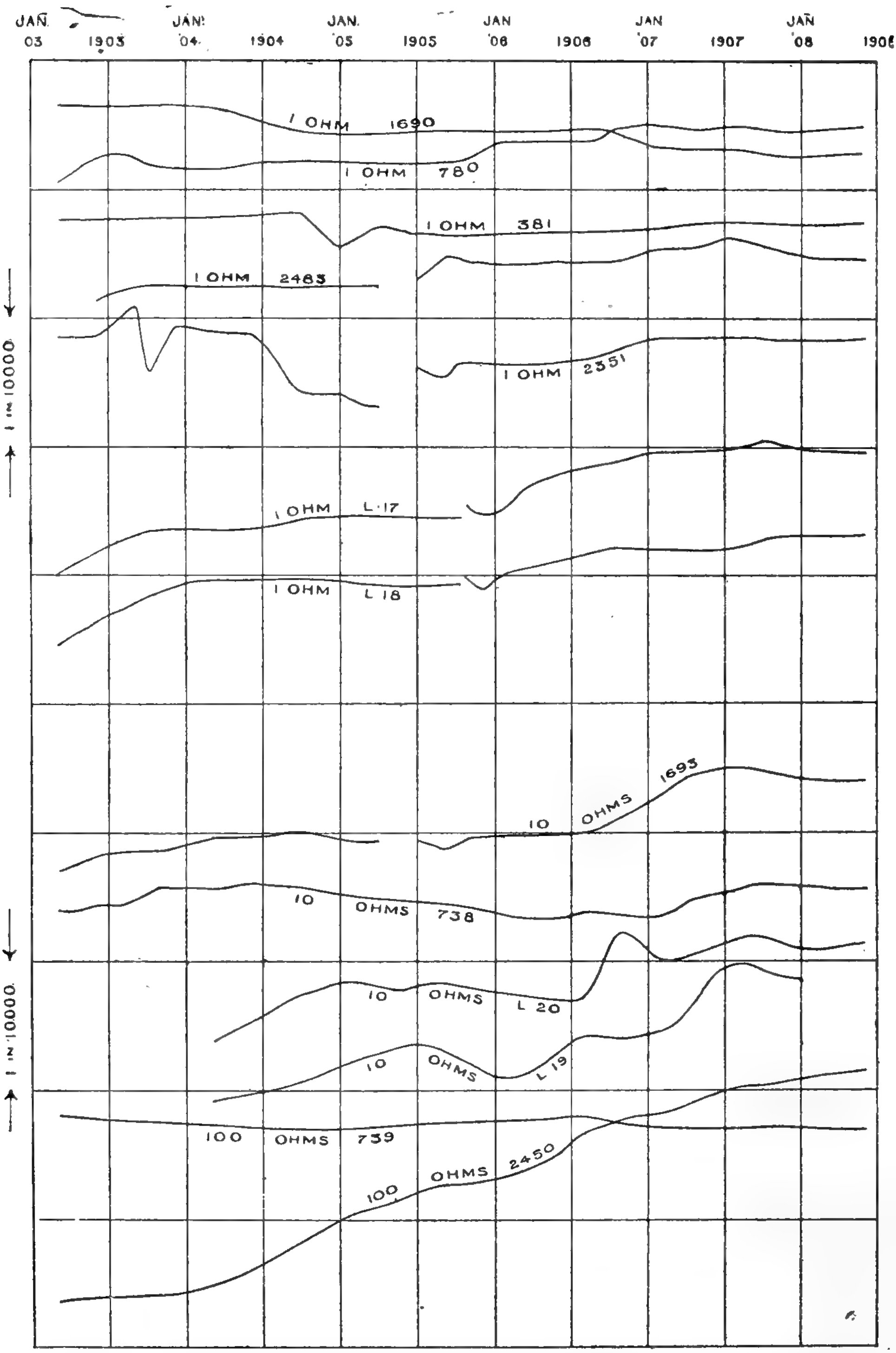


CHART I: Showing the Variations in Resistance of Manganin Standard Coils of Nominal Values, 1 Ohm, 10 Ohms, and 100 Ohms.

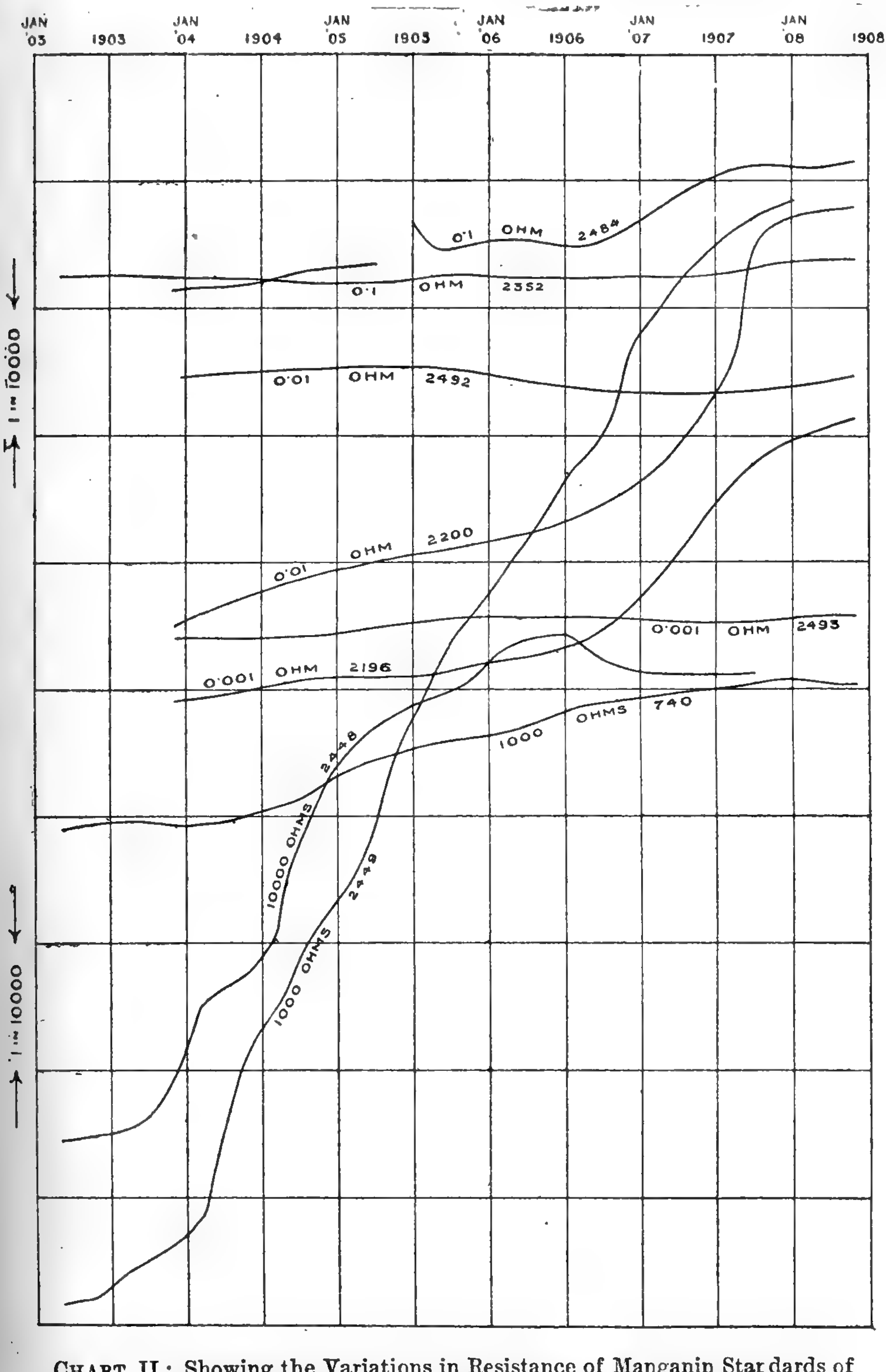


CHART II: Showing the Variations in Resistance of Manganin Standards of Nominal Values, 0·001, 0·01, 0·1 Ohm, and 1,000 and 10,000 Ohms.

other small changes are difficult to assign and are possibly due to variable humidity. The errors in the differences recorded are certainly less than 1×10^{-6} ohm.

The above is only part of the analysis of the differences which is in general made. Comparisons with coils other than units are also often desirable, but need not be dealt with here.

Table XI. gives the resistance of a number of manganin coils in the October of each year from 1903 to 1907, and charts Nos. 1 and 2 show the complete changes in most of the coils from March 1903 to June 1908. In Table XI. the resistances are given in the same month of each year in order to eliminate from the table (as much as possible) the effects of humidity on the resistances of the coils.

Resistances L·19, 2448, and 2449 were placed in atmospheres of varying humidities in the interval October 1907–April 1908, and hence the curves for these coils are not continued on the charts after January 1908.

Table XI.

Resistances in International Ohms at 17°·0 C.

Resistance Standard	Nominal Value	Oct. 1903	Oct. 1904	Oct. 1905	Oct. 1906	Oct. 1907
O.W. 2196	0·001 ohm	—	$0{\cdot}00099996_8$	$0{\cdot}00099997_8$	$0{\cdot}00100000_8$	$0{\cdot}00100014_0$
O.W. 2493	„	—	$0{\cdot}00100000_0$	$0{\cdot}00100001_4$	$0{\cdot}00100001_6$	$0{\cdot}00100001_1$
O.W. 2200	0·01 ohm	—	$0{\cdot}0100014_6$	$0{\cdot}0100016_9$	$0{\cdot}0100020_7$	$0{\cdot}0100041_1$
O.W. 2492	„	—	$0{\cdot}0100011_2$	$0{\cdot}0100011_0$	$0{\cdot}0100009_7$	$0{\cdot}0100009_7$
O.W. 2352	0·1 ohm	$0{\cdot}099998_5$	$0{\cdot}099998_0$	$0{\cdot}099998_4$	$0{\cdot}099998_4$	$0{\cdot}099999_5$
O.W. 2484	„	—	$0{\cdot}100009_0$	$0{\cdot}100011_0$	$0{\cdot}100011_1$	$0{\cdot}100017_4$
O.W. 1690	1 ohm	$1{\cdot}00004_4$	$1{\cdot}00002_5$	$1{\cdot}00002_5$	$1{\cdot}00002_5$	$1{\cdot}00000_7$
O.W. 780	„	$0{\cdot}99993_9$	$0{\cdot}99994_1$	$0{\cdot}99994_0$	$0{\cdot}99996_5$	$0{\cdot}99996_5$
O.W. 381	„	$1{\cdot}00009_6$	$1{\cdot}00009_8$	$1{\cdot}00008_4$	$1{\cdot}00008_8$	$1{\cdot}00009_2$
O.W. 2483	„	$1{\cdot}00000_4$	$1{\cdot}00000_2$	$1{\cdot}00002_4$	$1{\cdot}00002_4$	$1{\cdot}00003_5$
O.W. 2351	„	$0{\cdot}99999_6$	$0{\cdot}99998_2$	1.00000_5	$1{\cdot}00001_4$	$1{\cdot}00002_4$
L·17	„	$0{\cdot}99985_5$	$0{\cdot}99986_4$	$0{\cdot}99987_5$	$0{\cdot}99990_8$	$0{\cdot}99992_5$
L·18	„	$0{\cdot}99984_0$	$0{\cdot}99985_6$	$0{\cdot}99985_8$	$0{\cdot}99988_2$	$0{\cdot}99989_0$
O.W. 738	10 ohms	$9{\cdot}9987_5$	$9{\cdot}9987_8$	$9{\cdot}9986_4$	$9{\cdot}9985_8$	$9{\cdot}9987_9$
O.W. 1693	„	$10{\cdot}0000_5$	$10{\cdot}0002_0$	$10{\cdot}0001_8$	$10{\cdot}0002_8$	$10{\cdot}0004_7$
L·19	„	—	$9{\cdot}9995_1$	$9{\cdot}9997_1$	$9{\cdot}9998_5$	$10{\cdot}0003_7$
L·20	„	—	$9{\cdot}9995_5$	$9{\cdot}9996_2$	$9{\cdot}9999_2$	$9{\cdot}9999_8$
O.W. 739	100 ohms	$99{\cdot}999_6$	$99{\cdot}999_1$	$99{\cdot}999_6$	$99{\cdot}999_6$	$99{\cdot}999_0$
O.W. 2450	„	$99{\cdot}995_9$	$100{\cdot}000_2$	$100{\cdot}004_8$	$100{\cdot}009_2$	$100{\cdot}013_2$
O.W. 740	1000 ohms	$1000{\cdot}15_5$	$1000{\cdot}17_2$	$1000{\cdot}21_8$	$1000{\cdot}24_8$	$1000{\cdot}26_6$
O.W. 2449	„	$1000{\cdot}01_2$	$1000{\cdot}24_4$	$1000{\cdot}49_4$	$1000{\cdot}66_8$	$1000{\cdot}81_4$
O.W. 2448	10000 ohms	$10000{\cdot}2_4$	$10002{\cdot}4_0$	$10003{\cdot}5_7$	$10003{\cdot}8_2$	$10003{\cdot}7_4$

At first limiting our attention to the unit coils, we see from the charts that these have varied during the past five years by the following amounts :—

TABLE XII.

Coil	Maximum Change in Resistance in 5 years	Difference Value. Resistance in 1908 *minus* Resistance in 1903
1690	$3\cdot7 \times 10^{-5}$ ohm	$-3\cdot7 \times 10^{-5}$ ohm
780	4·6 ,,	4·6 ,,
2351	7·8 ,,	−0·2 ,,
2483	4·4 ,,	3·2 ,,
381	2·6 ,,	−0·2 ,,
L·17	10·2 ,,	9·6 ,,
L·18	8·8 ,,	8·8 ,,
	Mean = 6·0 ,,	Mean = +4·2 ,,

If we neglect L·17 and L·18 the mean value of the other five coils is $2\cdot2 \times 10^{-5}$ ohms greater in 1908 than in 1903.

Apart from the cause of these changes, it is interesting to form some idea of what interpretation of the differences might reasonably have been applied if mercury standards had not been the master standards. If the mean value of the seven coils had been taken as remaining constant, the error in five years would have amounted to 4·2 parts in 100,000. A comparison with coils of nominal values differing from unity might, however, be made, and such might largely influence the result.

The maximum changes which have taken place in the other resistance standards and the difference values (1908–1903 values) are given in Table XIII.

TABLE XIII.

Resistance Standard	Nominal Value	Maximum Change since 1903. Parts in 100,000	1908 Value *minus* 1903 Value. Parts in 100,000	Mean Difference. Parts in 100,000
O.W. 2196	0·001 ohm	22·4	22·4	+12·1
O.W. 2493	0·001 ,,	2·0	1·8	
O.W. 2200	0·01 ,,	33·0	33·0	+16·6
O.W. 2492	0·01 ,,	1·9	0·2	
O.W. 2352	0·1 ,,	2·0	1·4	+ 4·7
O.W. 2484	0·1 ,,	8·0	8·0	
O.W. 738	10 ohms	2·2	1·7	+ 6·5
O.W. 1693	10 ,,	8·0	7·2	
L·19	10 ,,	11·0	9·6*	
L·20	10 ,,	8·3	7·6*	
O.W. 739	100 ,,	1·2	−1·0	+ 8·5
O.W. 2450	100 ,,	18·0	18·0	
O.W. 740	1000 ,,	11·8	11·4	+50·4
O.W. 2449	1000 ,,	89·4	89·4	
O.W. 2448	10000 ,,	40·0	36·8	+36·8

Mean difference value (1908–1903 values) = +16·5 parts in 100,000.

Mean difference value (1908–1903 values) including the unit coils = +12·6 parts in 100,000.

* These are the difference values (1908–1904 values).

The mean difference in the values of all the manganin coils for 1908 and 1903 is 12·6 parts in 100,000. The oldest coils are 381 (seventeen years old), 780, 738, 739, and 740 (thirteen years old), and 1693 and 1690 (eight years old), the ages being approximate only. The remainder of the coils are from five to six years old.

The most constant coils belonging to various groups are :—

381—most constant of the unit coils.			
738	„	„	10 ohms coils.
739	„	„	100 „
740	„	„	1,000 „

In general, therefore, the older the coil the more constant does it appear to be.

With reference to the sudden changes in resistance, as shown by the curve for 2351 in 1903, of 381 in 1904–5, and of L·20 in 1906, we can offer no complete explanation ; but it is possible that variable humidity of the surrounding medium, such as might arise from the presence of a small quantity of moisture in the insulating oil, was responsible for part of these changes.

The breaks in the curves for 2483, 2351, L·17, L·18, 1693, and 2484 are due to these coils being away from the National Physical Laboratory ; they were being compared with the wire standards of the Reichsanstalt.

The increase in resistance of No. 2449 is phenomenal. The *daily* rate of change for 1906 is over four parts in 10,000,000 ; that is, in about twenty-two days the coil changed in resistance by about one part in 100,000. In April 1907 we attempted to measure the change from day to day, and for this purpose we compared 2449 and 740 every working day for four weeks. The results obtained are as follows :—

Day of Observation . .	1	3	5	8	10	12	15	17
Difference (2449–740) Parts in 100,000	52·05	52·15	52·30	52·35	52·25	52·30	52·55	52·65
Day of Observation .	19	22	24	26	29			
Difference (2449–740) Parts in 100,000	52·75	52·95	53·00	53·00	53·15			

The change was, therefore, a very gradual one, and easily detected. It is of interest to note that the rate of change for the last six months of 1907 is less than that for 1903–6.

The possible causes of the changes in the manganin resistances may be classified under the following heads :—

1. Change in structure of the alloy.
2. Surface action.
3. Humidity effect.
4. Change in the soldered joints connecting the wires of high-resistance coils to the current leads.
5. Change at the junctions of the potential leads with the resistance standard.

Only the first of these appears to fully explain the gradual rise in resistance. Causes 2 and 4 would have an inappreciable effect on very low resistances ; yet some of these—*e.g.* 2196—have changed by considerable amounts. Cause No. 5 would have no effect on high-resistance coils, since these are not provided with potential leads ; but Table XIII. shows that all of the high-resistance coils have changed. Cause No. 3 produces in general a cyclic change, and, while being without doubt a cause of variation, it cannot be modified to explain all the gradual increases in resistance, owing to the negligible effect of humidity on very low-resistance standards. Cause No. 1 appears, therefore, to have been the chief agent in the cases we have considered.

It is necessary, however, that we should say something about other manganin coils. In 1903 the resistances were measured of some manganin coils (1 to 5,000 ohms) in a box by R. W. Paul, London. The coils could not readily be immersed in oil, and the measurements were therefore uncertain to about 1 part in 100,000. The resistances were again measured in 1904, 1906, and December 1907. The maximum change in the resistance of any coil is 5 parts in 100,000, while the mean increase in resistance during 1903–7 is 4 parts in 100,000.

In 1902, and again in 1907, the resistances were measured of some manganin coils (1 to 10,000 ohms) in box No. 1723 by O. Wolff, Berlin. The maximum change in resistance during the period 1902–8 is about 6 parts in 100,000, and a few of the coils have kept practically constant. Many manganin coils in other boxes are known, however, to have changed very considerably.

It will be seen that of the manganin standards we have examined some have kept remarkably constant, while others are practically useless as standards. It must not be concluded, however, that all manganin resistances are subject to such changes. Drs. Jaeger and Lindeck have shown that the manganin standards of the Reichsanstalt keep very constant, and the manganin coils at the Bureau of Standards also appear to be of a fairly constant type, though subject to considerable cyclic changes owing to variable atmospheric humidity. The manganin standards reported on in this Appendix comprise *every standard resistance of manganin* in use in the Standards Department of the National Physical Laboratory.

APPENDIX II.

Specifications for the Practical Realisation of the Definitions of the International Ohm and International Ampere, and Instructions for the Preparation of the Weston Cadmium Cell.

(From the National Physical Laboratory.)

The following specifications have been prepared after consultation with various authorities, and will form a basis for discussion at the forthcoming Congress on Electric Units in London. They have not been authoritatively adopted, and are subject to amendment.

In the last Report specifications for the realisation of the international ampere and for the construction of the cadmium cell were given, the processes of preparation, &c., being described with considerable detail. These specifications appeal to a much wider circle than the present ones, for the latter are intended mainly to serve as a guide to the standardising institutions of the various countries in order to obtain, as far as possible, complete agreement in the units of electric measurements. Certain instructions, such as the purification of mercury, have therefore been omitted, but all which is thought to be essential for an exact reproduction of conditions is still included. Instructions for the erection of mercury standards have not previously been issued.

The International Ohm.

The international ohm shall be equal to the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14·4521 grammes in mass, of a constant cross sectional area, and of 106·300 centimetres in length, arranged in accordance with the following specification.

The column of mercury shall be of circular section, or nearly so, and shall be contained in a tube of suitable glass which has been carefully annealed. The tube shall be straight to the eye, and the maximum variation in its area of cross section shall not exceed 2 parts in 100. The tube is to be carefully calibrated, and the correction for its conicality determined.

In determining the weight of mercury contained by the tube when filled at the temperature of melting ice, the column of mercury is to be bounded by planes at the terminal cross sections of the tube. The tube should not be unduly heated, and it should be filled with mercury by exhaustion of air.

The axial length of the tube should be measured at 0° C. if possible, otherwise the coefficient of expansion of the glass should be determined and the axial length of the tube at 0° C. calculated from axial measurements made very near to that temperature. To facilitate measurements of the axial length, the ends of the tube should be ground very slightly convex.

For the electrical measurements the ends of the tube are to be connected to spherical bulbs of glass, the ends of the tube forming, approximately, portions of the internal spherical surfaces of the bulbs. Each bulb is to be provided with current and potential leads, the point of entry of the former being at the opposite end of a diameter of the bulb from an end of the tube. The potential lead shall be situated in a plane midway between the point of entry of the current lead and the end of the tube, and at right angles to the line connecting them.

Contact with the mercury shall be made by means of platinum wires.

The diameter of a bulb is to be from 30 to 33 times the diameter of that end of the tube to which it is connected.

If L is the axial length in centimetres of the mercury column contained by the tube at 0° C., W the weight of the column in grammes, and c the correction for the conicality of the tube, the resistance of the column at 0° C. is

$$c \frac{L^2}{(106\cdot300)^2} \cdot \frac{14\cdot4521}{W} = 0\cdot001278982\, c \frac{L^2}{W} \text{ international ohms.}$$

When the spherical bulbs are fitted to the ends of the tube and the whole filled with mercury, if r is the mean radius of the tube and r_1, r_2, the mean radii in centimetres of the terminal sections, the resistance at 0° C. between the potential leads is

$$0\cdot001278982 \frac{L^2}{W}\left\{c + \frac{0\cdot80r^2\left(\dfrac{r_1+r_2}{r_1\, r_2}\right)}{L}\right\}^* \text{international ohms,}$$

correct to 1 per cent. of the added resistance

$$0{\cdot}001278982 \frac{L}{W}\left\{ 0{\cdot}8\,0r \left(\frac{r_1 + r_2}{r_1\, r_2}\right)\right\}^*$$

* The end correction factor is given in these formulæ as 0·80: this value is, however, subject to amendment.

The electrical measurements are to be carried out at 0° C., the tube and spherical vessels being surrounded by melting ice and about 15 centimetres below the upper surface of the ice. The connecting wires employed for the current and potential leads must be thin, the flow of heat through them to the mercury being insufficient to warm the mercury so as to produce appreciable error.

The insulation resistance between the mercury column and the ice surrounding the tube must not be less than 10,000,000 ohms.

The current employed in comparing the mercury resistance with other resistances shall be limited by the condition that the mercury shall not be warmed sufficiently to produce appreciable error.

The mean of at least five tubes must be taken to determine the value of the mercury unit.

The mean of at least three fillings shall be taken as the value of the resistance of a tube.

Specification for the Practical Application of the Definition of the International Ampere.

Conditions under which silver is to be deposited to measure currents from 0·5 to 8 amperes:—

The solution shall consist of from 15 parts to 25 parts by weight of pure crystallised silver nitrate in 100 parts of distilled water free from chlorine. It shall be used for one determination of current only.

In cases in which it is desired to measure a current of about 1 ampere the anode shall consist of a disc or plate of pure silver about 60 square centimetres in area and 3 or 4 millimetres in thickness. It is supported by a silver rod riveted through its centre. The anode shall be inserted into a cup of filter paper separately supported.

The kathode shall consist of a platinum bowl about 10 centimetres in diameter and 7 centimetres in depth.

About 300 cubic centimetres of the silver-nitrate solution are to be placed in the kathode bowl, and the anode is to be supported near the top of the solution and is to be just covered by it. Not more than from 7 to 10 grammes of silver should be deposited.

(For the measurement of smaller currents, say from $\frac{1}{4}$ to $\frac{1}{3}$ ampere, a bowl holding about 60 cubic centimetres of solution may be used, the anode being proportionately reduced in size and from 2 to 3 grammes of silver being deposited.)

The deposit should be rinsed with distilled water free from chlorine until the addition of a drop of neutral solution of sodium chloride in water, to the wash water, produces no milkiness. The kathode bowl is then nearly filled with distilled water and left for at least three hours ; it should be rinsed three times, the last of these wash waters remaining in the bowl for ten minutes. This last wash water should give no milkiness when added to a neutral solution of sodium chloride in water. The deposit is to be dried in an electric oven at a temperature of about 160° C.; it is placed in a desiccator to cool, and is afterwards weighed.

The mass of the deposit, expressed in grammes, divided by the number of seconds during which the current has been passed and by 0·001118, gives the mean current in amperes.

Preparation of the Weston Cadmium Standard Cell.

The cell has mercury for its positive electrode, and an amalgam consisting of from 12 to 12·5 parts by weight of cadmium in 100 parts of the amalgam for its negative electrode. The electrolyte consists of a saturated solution of cadmium sulphate, and solid cadmium sulphate is contained within the cell. A paste, consisting of solid mercurous sulphate, mercury, and solid cadmium sulphate, rests on the positive electrode.

For the positive electrode, pure distilled mercury should be used.

The amalgam may be made either by electrodeposition or by mechanical mixing. It should be fused and freed from oxide by washing with dilute sulphuric acid.

For the preparation of the cadmium sulphate crystals and solution, commercially pure recrystallised cadmium sulphate should be dissolved in pure distilled water so as to form a clear saturated solution. Evaporation at about 35° C. is then allowed to proceed, when crystals separate from the solution. The crystals are washed with successive small quantities of distilled water, and part of them is dissolved in distilled water to form a saturated solution. The solution should be neutral to congo red.

The mercurous sulphate should be quite pure, and its crystals should not be so small as to have an abnormal solubility or so large as to be inefficient as a depolariser. The following is an example of a method for preparing the salt satisfactorily :—

Add 15 cubic centimetres of pure strong nitric acid to 100 grammes of pure mercury, and place on one side until the action is over or nearly over. Transfer the mercurous nitrate thus formed, together with the excess of mercury, to a beaker containing about 200 cubic centimetres of dilute nitric acid (1 volume of acid to about 40 volumes of water); a clear solution should result. Prepare about 1 litre of dilute sulphuric acid (1 volume of acid to 3 of water), and while the mixture is hot add the acid mercurous nitrate solution to it. The solution should be added as a very fine stream from the narrow orifice of a pipette, and the mixture violently agitated during the mixing. Mercurous sulphate is precipitated. Decant the hot clear liquid and wash the precipitate twice by decantation with dilute sulphuric acid (1 volume of acid to 6 of water). The precipitate should then be filtered and washed three times with dilute sulphuric acid (1 to 6), and afterwards 6 or 7 times with saturated cadmium sulphate solution to remove the acid. The mercurous sulphate should then be flooded with saturated cadmium sulphate solution and left for one hour, after which the solution is tested with congo red paper. In general no acid will be detected, and if so the mercurous sulphate is ready for use.

To set up the cell the H form of vessel is the most convenient. The platinum wires inside the vessel should be amalgamated by passing an electric current to each in turn through an acid solution of mercurous nitrate. The vessel must afterwards be washed out twice with dilute nitric acid and several times with distilled water; it must be free from stains and scrupulously clean; it is dried by the application of heat. The amalgam is fused and its surface flooded with very dilute sulphuric acid: sufficient of it to cover the amalgamated platinum wire completely should then be introduced into one of the limbs of the H vessel. To free from acid the amalgam may be remelted and washed with distilled water. Into the other limb of the vessel sufficient mercury is introduced to cover the amalgamated platinum wire completely. Then the paste, finely powdered crystals of cadmium sulphate, and saturated cadmium sulphate solution are added in the order named and the cell sealed.

Its electromotive force at 20° C. is $1{\cdot}018_5$ volt.

The electromotive force at any other temperature (t) may be obtained from the equation :—

$$E_t = 1{\cdot}018_5 - 0{\cdot}000038\,(t-20) - 0{\cdot}00000065\,(t-20)^2,$$

the limits of temperature being—(these have not yet been fixed).

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 SCHUSTER.

THE results of the magnetic observations at the Falmouth Observatory have been published in the Annual Report of the National Physical Laboratory, as well as in that of the Royal Cornwall Polytechnic Society.

The mean values of the magnetic elements for the year 1907 were :—

Declination	18° 0′·4 W.
Horizontal Force . .	0·18799 C.G.S.
Vertical Force . . .	0·43330 C.G.S.
Inclination	66° 32′·7 N.

The Observatory has been inspected by Mr. T. W. Baker, who found the instruments recording satisfactorily. He also took some absolute observations, which accorded well with those taken by Mr. Kitto.

The Committee are informed that the observatory at Eskdalemuir has only commenced work during the current year, so that comparative results are not yet available, while the disturbances due to electric traction in the neighbourhood of London have a natural tendency to increase. The maintenance of magnetic work at Falmouth in full efficiency has thus lost none of its importance. It is most desirable to secure this for at least another year, and the Committee ask for reappointment, with a grant of 50*l*.

Geodetic Arc in Africa.—Report of the Committee, consisting of Sir GEORGE DARWIN (*Chairman*), Sir DAVID GILL (*Secretary*), Major C. F. CLOSE, *and* Sir GEORGE TAUBMAN GOLDIE, *appointed to co-operate in the Measurement of a further portion of the Geodetic Arc of Meridian North of Lake Tanganyika.* (*Drawn up by the Chairman.*)

ON May 7, 1907, Sir David Gill, Sir George Goldie, and Sir George Darwin wrote a joint letter to the Secretary of State for the Colonies suggesting that advantage should be taken of the presence of a Boundary Commission in Uganda to measure a further portion of the arc of meridian of the 30th degree of east longitude, and offering, on behalf of the Royal Society, the Royal Geographical Society, the Royal Astronomical Society, and the British Association, to contribute the sum of 1,000*l.* towards the cost of the work.

This Committee was appointed at the meeting of the Association held at Leicester.

On August 5 and August 20 the Secretary of State wrote to Sir David Gill agreeing to the proposal, and offering the post of skilled observer to Mr. G. T. McCaw.

On September 4 the Foreign Office suggested to the Government of the Congo Free State the desirability of their co-operation. This was agreed to on December 13, and that Government agreed further to send and pay for a skilled observer, namely, M. Dehalu, of Liège.

It was agreed that the whole operation of measuring the arc should be under the joint control of the Boundary Commissioners.

Technical instructions were handed to Mr. McCaw on his departure from England, and he arrived at Toro, a point on the arc, on March 14, 1908, having with him all his instruments. He was joined by M. Dehalu at Toro on April 16, 1908.

The state of the work, as described in letters from Colonel Bright, the officer in charge of the Boundary Commission, and from Mr. McCaw on May 9, was as follows :—

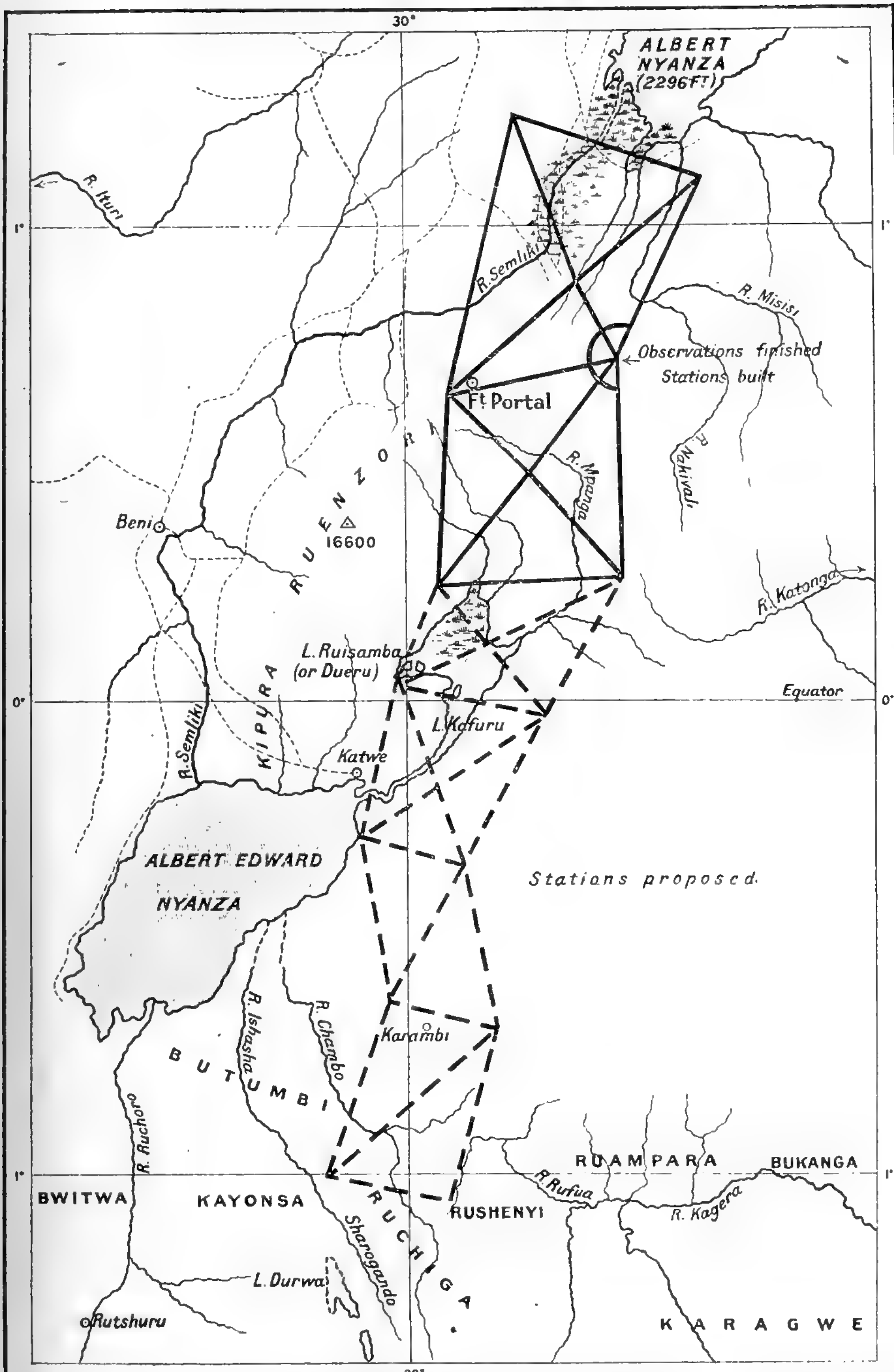
The arc-measuring party consists of Captain Jack, R.E. ; Mr. McCaw ; two British non-commissioned officers ; one Belgian officer ; and M. Dehalu.

The preliminary reconnaissance of the arc from Lake Albert to 1° of S. latitude had been completed by the Commission. The final reconnaissance of two figures had been completed and six stations had been built. The base had been selected and marked and observations at one station had been completed.

On the annexed map the portion of the survey, for which the stations are built and the corresponding triangles measured, are shown with firm lines. The proposed triangles for the rest of the arc are shown in dotted lines.

The information contained in this report has been furnished by the War Office through Major C. F. Close, R.E.

PROGRESS ON ARC UP TO 9TH MAY 1908.



Scale $\frac{1}{2,000,000}$ or 1·014 Inches to 32 Miles

0 10 20 40 60 Miles

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord McLaren (*Chairman*), Professor Crum Brown (*Secretary*), Sir John Murray, Professor F. W. Dyson, *and* Mr. R. T. Omond.

Since the closing of the Ben Nevis Observatories in October 1904 the Committee has directed its attention to the completion of the publication of the meteorological observations made at the observatories. The observations from the opening of the observatories, 1883, to the end of 1897, have been published *in extenso* in volumes xxxiv., xlii., and xliii. of the 'Transactions' of the Royal Society of Edinburgh. The records down to the end of 1900 are in type, and the printing of those of the remaining years is being proceeded with.

The British Association last year gave a grant of 25*l.* to assist the publication of these records. This has been wholly expended in printing. This sum and grants received from other sources have provided sufficient funds to ensure the publication in the 'Transactions' of the Royal Society of Edinburgh of all the hourly observations made at the Ben Nevis Observatories, and of certain discussions of these observations made by the late Dr. Buchan, Mr. R. T. Omond, and others.

The arrangements for the publication of the final volume of observations having now been completed, the Committee do not desire reappointment.

The further Tabulation of Bessel Functions.—Report of the Committee, consisting of Professor M. J. M. Hill (*Chairman*), Dr. L. N. G. Filon (*Secretary*), *and* Professor Alfred Lodge.

Further progress has been made this year with the calculations. The values of log sin a and thence of a have been worked out for $n=\frac{1}{2}$, $1\frac{1}{2}$, $2\frac{1}{2}$, . . . $6\frac{1}{2}$ (the notation being identical with the one employed in last year's Report). Values of log $\frac{x^a}{k}$, where $k=\frac{1}{8}(4n^2-1)$, have also been calculated. These were found to give a sequence suitable for interpolation. The accuracy of the results have been tested from the formula

$$\text{sec. } (a_{n+1}-a_n)=R_n R_{n+1}.$$

The work, however, is not sufficiently advanced for the tables to be printed. As the greater part of the work will now be done by members of the Committee personally, the necessity for a grant disappears, and the Committee therefore ask for reappointment without a grant.

Investigation of the Upper Atmosphere by means of Kites in co-operation with a Committee of the Royal Meteorological Society.—Seventh Report of the Committee, consisting of Dr. W. N. SHAW (*Chairman*), Mr. W. H. DINES (*Secretary*), Mr. D. ARCHIBALD, Mr. C. VERNON BOYS, Dr. R. T. GLAZEBROOK, Dr. H. R. MILL, Professor A. SCHUSTER, *and* Dr. W. WATSON. (*Drawn up by the Secretary.*)

MEETINGS of the Joint Committee were held in the rooms of the Royal Meteorological Society on October 16, 1907, and January 22 and May 5, 1908.

During the year the Committee arranged with Captain Ley that he should send up registering balloons on some of the days appointed by the International Committee, more particularly during the period July 27 to August 1, 1908, and also that he should continue the investigation on the direction and velocity of the upper currents by the method devised by himself, which requires only one theodolite.

Captain Ley has carried out a valuable series of observations, and the results will be published in due course.

The grant of 25*l.* made last year by the Association has been allotted to the Howard Estate Station, at Glossop Moor, for the purpose of supplementing the observations made there by means of a captive balloon, and a report on the subject by Professor Petavel is appended.

The Committee ask for reappointment and for a grant of 25*l.*

The Captive Balloon at the Howard Estate Kite Station.
By J. E. PETAVEL, *F.R.S.*

The funds granted by the British Association Committee and by the Royal Meteorological Society have been used to erect the necessary gasometer and generating plant at Glossop.

The gasometer, of some 250 cubic feet capacity, is arranged so that by a manipulation of the counterweights the pressure can be varied, and the gas passed out into the balloon or drawn back from it as may be required.

Rubber balloons are used having a capacity of some 200 cubic feet. These are filled whenever the wind proves insufficient to raise a kite, and are sent up usually at sunset. The height reached varies from 5,000 feet above sea level in a calm to 1,500 feet or 2,000 feet in a light breeze. Fine steel wire, weighing 4 lb. per mile and having a breaking strain of 50 lb., is used for the ascent.

Up to the present an ordinary Dines kite meteorograph has been employed.

The balloon is deflated and the gas drawn back into the gasometer each evening.

At present some thirty ascents have been made, which are of considerable value, as they maintain the continuity of the observations on days on which it is not possible to send up a kite.

The apparatus has also been used by Captain Ley and others for pilot-balloon ascents.

Seismological Investigations.—Thirteenth Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Dr. J. MILNE (*Secretary*), 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 J. W. JUDD, 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, *and* Mr. NELSON RICHARDSON. (*Drawn up by the Secretary.*)

[PLATES I.–IV.]

CONTENTS.

I. *General Notes.*

FOR assistance in the compilation of this report and earthquake registers, together with general services rendered in the laboratory, my thanks are due to Mr. S. Hirota, Mr. J. H. Burgess, and Mr. H. C. O'Neill. For financial support, which extends to the observatory at Bidston, I have to thank the Royal Society, the British Association, the administrators of the Gray Fund, and Mr. Richard Cooke. The Committee ask to be reappointed and for a grant of 60*l*.—J. MILNE.

Registers.—During the past year the registers issued are contained in Circulars Nos. 16 and 17. They refer to Shide, Kew, Bidston, Edinburgh, Paisley, Haslemere, San Fernando, Malta, Cape of Good Hope, Azores, Calcutta, Bombay, Kodaikanal, Batavia, Cairo, Trinidad, Toronto Victoria, B.C., Perth, Sydney, Christchurch, Lima, Irkutsk, Beirût, Cordova, Baltimore, and Honolulu.

Records have not yet been received from Melbourne and Arequipa, while registers from Philadelphia, Mexico, Wellington, and Mauritius should be brought up to date.

The Sydney Register for August 1906, Circular 16, omits any reference to the disturbance which on the 17th of that month destroyed Valparaiso. The omission is due to the fact that the original seismogram had been loaned to the International Seismological Association, and was not returned in time for publication in its right place. It, however, appears in Circular 17.

In other cases also the International Seismological Association have communicated directly with stations which for some years past have kindly co-operated with the British Association. The result has been that serious inconvenience has been experienced. In connection with this attention may be drawn to the following resolution of the Council of the Royal Society of London, dated December 6, 1906 :—

'Resolved—That the Council are of opinion that no change should be made in the practice whereby all seismological reports and observations for the United Kingdom are collected and transmitted by Professor Milne.'

It is fully recognised that every station which has kindly given assistance to the British Association Seismological Committee is an independent unit, and will therefore act upon such lines as seem best fitted to advance seismological investigation.

All circulars issued by the British Association Committee are sent not only to co-operating stations, but to others who express a wish to receive them. It has been thought advisable, however, not to send original seismograms anywhere by post, since on several occasions these have been lost. As far as possible photographic copies are sent to those who desire them.

Instruments.—In January and February 1907 two single-boom instruments were despatched to Capt. H. G. Lyons, Director-General Survey Department, Egypt. Each gives an open diagram (similar to Plate II.), and is oriented at right angles—one recording N.S. motion and the other E.W. motion. The station is at Helwan, near Cairo.

On January 21 a similar instrument was forwarded to W. G. Davis, Esq., Director of the Argentine Meteorological Observatory at Buenos Ayres. In October a fourth instrument, also giving an open diagram, was despatched to the order of the Agent-General for South Australia, to Adelaide.

In May 1908 a single-boom instrument was forwarded for the Cosego del Servicio Geográfico, Madrid ; while in June a twin-boom seismograph was constructed to be used by the National Physical Laboratory in their new station at Eskdalemuir, South Scotland.

Catalogues.—Considerable time has been spent in cataloguing the papers and books which relate to earthquake phenomena. Those in the English language have been completed, and Mr. O'Neill is now engaged upon those in foreign languages.

Time Signals.—The clock which gives us the time for the instruments at Shide is regulated by a Greenwich signal which is sent daily to all chief post offices throughout Great Britain. From time to time this signal, which is not visible to the public, is kindly given to me by the officials at the General Post Office at Newport. This involves a journey of two miles. To avoid this, and to assure greater accuracy, an attempt was made to obtain this signal at Shide. With this object in view the Astronomer-Royal, and subsequently the Council of the British Association, wrote to the Postmaster-General. It was pointed out that the observatory at Shide 'has been of universal interest and of recognised public importance. This station serves as a centre for stations in many of our colonies and in foreign countries. Many of these foreign and colonial stations were established as the direct result of the action taken by the Foreign Office, the Colonial Office, and the India Office, whose assistance was given partly on the ground that the object in view was considered to be of practical value to her late Majesty's Government. The Royal Observatory at Greenwich, and other observatories, refer to Professor Milne in matters of earthquake phenomena; and his observations throw light upon certain cable interruptions, indicating the times when "regulators" and other instruments found in observatories may have been disturbed. But, for the precise rectification of these observations, it will be highly desirable for Professor Milne to receive time signals. Inasmuch as the observations made at Shide and the co-operating stations, directly or indirectly are of assistance to several Government departments, the Council of the British Association desire to urge you to authorise the transmission of the time signal to Professor Milne, not as a member of the public, but as an official carrying out observations which are of service to the State.' From the General Post Office the matter was referred to the Lords Commissioners of the Treasury. When it was found that the only condition under which the signal could be obtained was 'the usual rental terms,' the rental for the wire being 22*l.* per annum, under an agreement for five years, together with the payment for installation, which was very high, the correspondence closed.

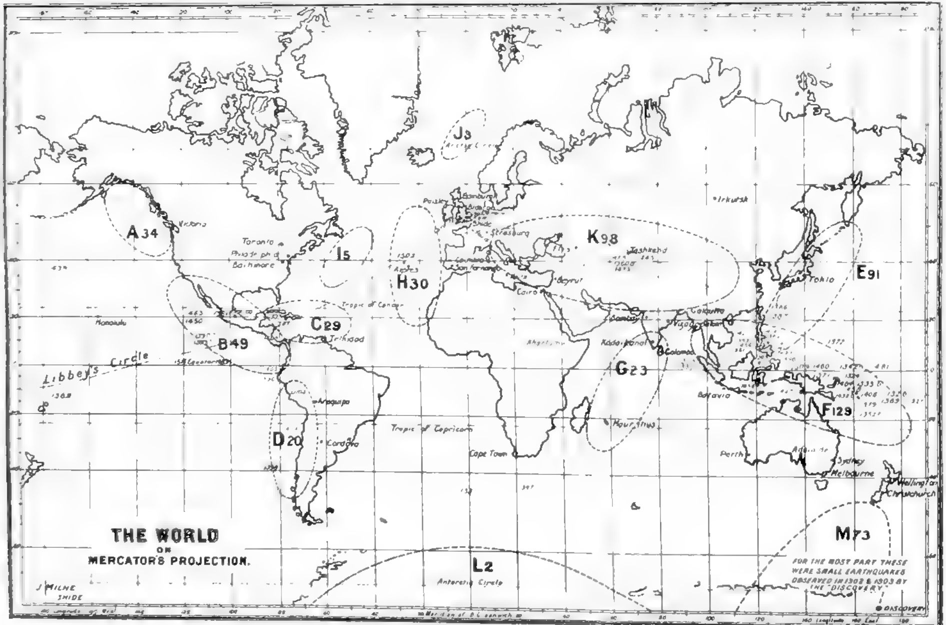
II. *Sites of Stations.*

Perth, Western Australia.[1]—The instrument is established at the observatory, which is situated on a hill 200 feet high quite away from the city. The building stands in the middle of a reserve of 11 acres and the traffic is slight. About a quarter of a mile away there is an electric tram. The seismograph is mounted on a concrete pedestal, and the clockwork on a marble slab on the top of solid brickwork, the whole being embedded in the concrete floor of the basement of the dome building. The character of the soil all round Perth is loose sand, which transmits vibrations only too well. Mr. Cooke, the Government Astronomer, says, 'We have had a lot of trouble and have taken rather unusual precautions to get rid of these vibrations in our transit house, but without any great success.' The Perth Mint authorities have had practically to give up their standard weighings owing to the impossibility of obtaining sufficient stability for their balances. They are right in the centre of the town. The sand seems to be in a state of perpetual quiver, and it is impossible to keep mercury steady—unless in an amalgamated trough—on any of our piers.

Lima.—The observatory is in the Exhibition Gardens, one mile south of the cathedral. Long. 79° 21′ 5″·2 W. of Paris. Lat. 12° 3′ 5″·8 south. Lima is built on a gently sloping plain formed of ejecta from Rimak during recent times. It is bounded on three sides by foot-hills or spurs of the Andes. Formation is gravel and conglomerate resting on andesites. Distance from sea, 4 miles; height, 400 feet; slope to the sea, $1\frac{1}{2}$ per cent.; foundations for the pillar and table are stone and cement to a depth of 10 feet. The boom runs north to south, the clock-box being at the south end.—Mr. H. HOPE-JONES, Geographical Society, Lima.

[1] Also see *B.A. Reports*, 1905, p. 84; 1906, p. 93; 1907, p. 87.

Origins for 1907 are indicated by their B.A. Shide Register number. Earthquake districts are indicated A, B, C, &c., and the number of Earthquakes since 1899 which originated from these is expressed in large numerals.



Illustrating the Report on Seismological Investigations

III. *On the Orientation of an Instrument with regard to the Building in which it is placed.*

At Shide, in the Isle of Wight, one portion of the observatory runs east and west. It has two north and south cross-walls; it is therefore very much more stiff in an east and west direction, or along its length, than in a direction at right angles. Storms generally strike the building from the south or south-west—that is to say, in the direction it is most likely to yield. In the building there are two very heavy horizontal pendulums, one of which points to the south and the other towards the east. At the time of strong winds, or even in light gales the latter pendulum, even in spite of damping arrangements, responds to wind impacts from the south or south-west. It does this to such an extent that during stormy weather it is useless as a recorder of earthquakes. I may add, the building is very solidly constructed; the support for the pendulum is a heavy mass of concrete entirely free from the foundation of the building. The pendulum which points north, south, or end on to the direction from which gusts of wind come, remains quite steady even during the heaviest of storms. Both pendulums are attached to the same support, which is a lamp-post embedded in the concrete foundation already mentioned.

IV. *The Large Earthquakes of* 1907.

On the accompanying map (Plate I.) we find the origins of large earthquakes which have occurred during 1907 indicated by their numbers as given in the Shide Register. The accuracy of the position of an origin which is indicated by the position of a number greatly varies, and is naturally dependent upon the data available for its determination. In certain instances a number only means that a particular disturbance originated within a certain district. For the year 1907 we see that certain of these districts were entirely free from megaseismic disturbances. The area which suffered the greatest disturbance was district F. This and its Himalayan continuation is one where irregularities of surface contour are pronounced, and it is therefore a district in which seismic instability should be expected. The following table gives the number of large earthquakes which have occurred in the principal earthquake-producing regions since 1899:—

		1899	1900	1901	1902	1903	1904	1905	1906	1907	Total.	Ratio to D.
East Pacific	A	13	9	3	2	3	0	2	2	0	34	1·6
	B	5	4	10	7	6	0	4	3	10	49	2·3
	C	4	6	4	6	3	0	0	4	2	29	1·4
	D	9	1	1	3	1	0	0	4	2	21	1·0
	Total	31	20	18	18	13	0	6	13	14	133	
West Pacific	E	18	3	7	9	9	14	9	15	7	91	4·3
	K	4	2	8	22	22	5	15	14	6	98	4·7
	F	8	11	12	14	10	9	16	24	25	129	6·1
	Total	30	16	27	45	41	28	40	53	38	318	
Grand total		61	36	45	63	54	28	46	66	52	451	

The first four districts are on the eastern side of the Pacific and in the Caribbean Sea, while the last three refer to the western side of the Pacific and the Himalayan ridges. The totals for these groups of districts show that the greatest seismic activity has been on the Asiatic side of the Pacific Ocean, particularly in the East Indian Archipelago. The least disturbed district has been the west side of South America. Another feature of interest shown by these totals is that from the year 1902 they rise and fall together; that is to say, seismic frequency on the two sides of the Pacific has fluctuated similarly. From this we may infer that seismic frequency in a district is not entirely governed by local influences, but largely by influences which extend over very large areas. As illustrative of these latter influences attention may be called to the redistribution of surface materials by ocean currents, or to stresses which may accompany unusual changes in the path followed by the pole of our earth.

V. *After-shocks of the Jamaica Earthquake, January* 14, 1907.

In an official report, No. 33*a*, on the earthquake of January 14, 1907, by Maxwell Hall, the time given for the commencement of the main disturbance is 3.29 P.M. (Jamaica time). The difference in longitude between Kingston and England is equivalent to 5h. 7m., and the time which large waves would take to travel between these places or 67° would be 43m. The time at which this particular phase of motion would be recorded in England would approximately be 21h. 19m. (G.M.T.) Inasmuch as Mr. Maxwell Hall's time refers to an observation made at Chapleton, and not at Kingston, we should expect the arrival of waves in England to be one or two minutes earlier than the time we have just given, and as a matter of fact they were recorded at the Isle of Wight at 21h. 17m. During the night of the 14th and 15th, we learn from the same report that 15 shocks were counted at Kingston. The times at which these occurred are not given, but as they appear to have been noted by persons out of doors we regard them as the more violent members of a much larger series. In the Isle of Wight small disturbances were recorded on the 14th at 23.40, 23.45, 23.52, and on the 15th at 0.2, 0.22, 0.32, 0.41, 0.43, and 0.45. We cannot say with certainty that these had their origin in the West Indies; it is, however, extremely likely that this is the case. With regard to many of the shocks in Jamaica, the times of which are given by Mr. Maxwell Hall, the case is different. Between January 14, 7.5 P.M., and July 5, 2.10 P.M. (Jamaica time), 148 disturbances were recorded. Corresponding to 51 of these a seismograph in the Isle of Wight shows groups of tiny tremors, each of which was recorded at practically 43 minutes after a shock in Jamaica. The conclusion therefore is that the tremor groups represent after-shocks which have been sufficiently intense to traverse a distance greater than the width of the Atlantic. They do not appear to have been recorded at Strassburg, Göttingen, or Laibach, although the distance of these places is but little greater than the distance to the Isle of Wight. As this is the first time that a series of after-shocks has been recorded so far from their origin, and as the records of the same illustrate the high sensibility of the Milne horizontal pendulum, I give a list of these movements.

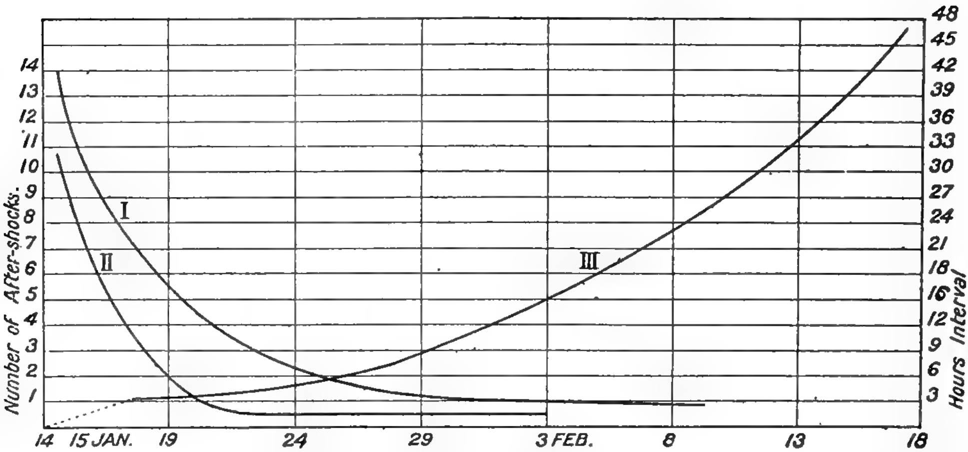
After-shocks of the Earthquake at Jamaica, which were recorded in England, January 14, 1907.

———	Jamaica Time	G.M.T.—Time when Shock should reach England	G.M.T.—Time when a Disturbance was recorded in England
2. January 14 .	8.3 P.M.	January 15, 1.53	1.52
3. " .	9.2 P.M.	2.52	2.53
4. " .	10.0 P.M.	3.50	3.39 and 3.51
5. " .	11.15 P.M.	5 5	5.4
6. January 15 .	1.40 A.M.	7.30	7.25, 7.40
7. " .	3.0 A.M.	8.50	8.45 to 8.50
8. " .	3.30 A.M.	9.20	9.19
9. " .	6.0 A.M.	11.50	11.45
10. " .	10·0 A.M.	15.50	15.45
11. " .	11.25 A.M.	17.15	17.14
12. " .	11.58 A.M.	17.48	18.12
13. January 16 .	2.55 A.M.	8.45	8.45 to 8.57
14. January 17 .	11.30 A.M.	17.20	17.19
15. January 18 .	11.30 A.M.	17.20	17.20
16. January 19 .	3.0 A.M.	8.50	8.50
17. " .	9.30 A.M.	15.20	15.22
18. " .	10.50 A.M.	16.40	16.35
19. January 21 .	6.0 P.M.	23.50	23.45
20. January 28 .	4.33 A.M.	10.23	10.18
21. " .	8·0 A.M.	13.50	13.53
22. January 30 .	7.21 A.M.	13.11	13.11
23. " .	8.20 A.M.	14.10	14.11
24. February 4 .	4.0 A.M.	9.50	9.45
25. " .	7.0 A.M.	12.50	12.55
26. February 5 .	1.30 A.M.	7.20	7.11
27. " .	5.15 A.M.	11.5	11.15
28. " .	10.59 P.M.	February 6, 4.49	4.38
29. February 6 .	2.55 A.M.	8.45	8 to 9
30. February 10 .	12.20 A.M.	6.10	6.10
31. " .	2.0 P.M.	19.50	19.48
32. February 11 .	5.30 P.M.	23.20	23.22
33. February 22 .	6.15 P.M.	February 23, 0.5	0.5
34. February 28 .	7.40 A.M.	13.30	13.35
35. March 1 . .	4.15 A.M.	10.5	10.7
36. March 8 . .	4.15 A.M.	10.5	10.4
37. March 9 . .	5.45 A.M.	11.35	11.30
38. March 11 . .	1.50 A.M.	7 40	7.42
39. March 14 . .	11.0 P.M.	March 15, 4.50	4.53
40. March 17 . .	6.30 A.M.	12.20	12.15
41. " . .	7.45 P.M.	March 18, 1.35	1.20
42. March 19 . .	6.10 A.M.	12·0	12.7
43. March 27 . .	8.55 A.M.	14.45	14.40
44. March 28 . .	8.30 A.M.	14.20	14.25
45. April 16 . .	7.0 A.M.	12.50	12.58
46. May 1 . .	3.45 P.M.	21.35	21.25
47. " . .	8.30 P.M.	May 2, 2.20	2.20
48. May 3 . .	11.10 A.M.	17.0	17.2
49. June 13 . .	1.18 A.M.	7.8	7.1
50. June 16 . .	11.0 A.M.	16.50	16.56
51. July 1 . .	5.10 A.M.	11.0	11.1
52. July 5 . .	2.10 P.M.	20.0	20.3

The decay in seismic activity, as indicated by a decrease in the frequency of after-shocks, is shown by the left-hand curves in fig. 1.

FIG. 1.

After-shocks of the Jamaica Earthquake, January 14, 1907.



I = After-shocks in Jamaica.
II = After-shocks which reached Great Britain.
III = Mean time intervals between after-shocks in Jamaica.

The Time Intervals between After-shocks.

As we recede from the primary shock the intervals between the after-shocks ought to become greater and greater, the increase in time interval indicating the nearness of approach to complete settlement. But in taking means of the intervals, as pointed out by Mr. O'Neill, a grave error may creep in by reckoning the means over arbitrary periods. In this way, to reckon the mean interval between the shocks for each day, three days, or each week, may or may not give any satisfactory result. It is mere chance in either case. But if we take the intervals over a sufficiently long period, and take means at points where the intervals have appreciably increased, we stand to obtain a result which more nearly approaches a true statement of the case. Thus means were first taken from day to day between January 14 and February 17, and the daily means worked out as follows: 1h. 19m., 2h. 31m., **5h. 20m.**, **5h. 1m.**, 3h. 11m., 2h. 41m., 4h. 48m., **6h. 21m.**, 3h. 38m., 5h. 0m., 11h. 51m., **19h. 30m.**, 10h. 52m., 18h. 40m., 14h. 10m., 6h. 38m., 18h. 18m., **28h. 0m.**, 23h. 55m., 24h. 10m., 13h. 57m., 7h. 10m., 8h. 28m., **35h. 8m.**, 6h. 5m., **82h. 40m.** Now it will be noticed that there are appreciable increases on the 17th, when the mean becomes about 5 hours. Another occurs on the 21st, when the interval has reached 6h. 21m. On the 25th it has become 19h. 30m., on the 31st, 28h. 0m., on February 6, 35h. 8m., and on the 11th, 82h. 40m.

If, then, we take means at these points we obtain results as follows, which show a constant increase in the time intervals as the distance from the primary shock increases.

Between January 14	and January 17,	for 24	intervals, the mean is	3h. 10m.
„ „ 17	„ 21,	„ 27	„ „	3h. 48m.
„ „ 21	„ 25,	„ 12	„ „	7h. 21m.
„ „ 25	„ 31,	„ 15	„ „	12h. 3m.
„ „ 31	and February 6,	„ 14	„ „	14h. 46m.
„ February 6	„ 17,	„ 4	„ „	46h. 52m.

The right-hand curve in fig. 1 shows the rate at which the intervals between after-shocks increased and seismic stability was approached. This curve, which should be the inverse of the upper curve in the left-hand side of the figure, is now shown, I believe, for the first time.

VI. *On the Dissipation of Earthquake Motion as measured by Amplitude and Duration.*

In order to obtain some idea of the manner in which a very large earthquake approaches extinction as it radiates, a comparison has been made of the amplitude and duration of motion of twenty-two large earthquakes, as recorded by instruments installed at varying distances from megaseismic origins.

The first question which arises relates to the comparability of the records. The instruments which give the records here used are, for the most part, the type adopted by the British Association—viz., Milne horizontal pendulums. A single record of a world-shaking earthquake from one of these instruments or from any other instruments would by two observers be interpreted for amplitude in a similar manner. For duration, however, this would not necessarily be the case. An examination of the film by one observer might make the duration a few minutes longer or shorter than that determined by another observer. Again, two similar and similarly adjusted instruments beneath the same roof may yield records showing slight differences, particularly with regard to duration. A complexity of factors conspire to render seismograms obtained from what we regard as similar, similarly adjusted, and similarly installed seismographs not strictly comparable. They are, however, to a certain extent comparable, and an estimate of this comparability may be obtained by an examination of a series of teleseismograms obtained from instruments installed over an area like that of Great Britain, each part of which is practically at the same distance from all very distant origins. In Britain we have stations at Shide (Isle of Wight), Kew, Bidston (near Liverpool), and at Edinburgh, each of which is provided with British Association pendulums. The foundations at these places are respectively chalk, alluvium, red sandstone, and volcanic rock. The records for amplitudes for earthquakes with distant origins have been as follows.[1]

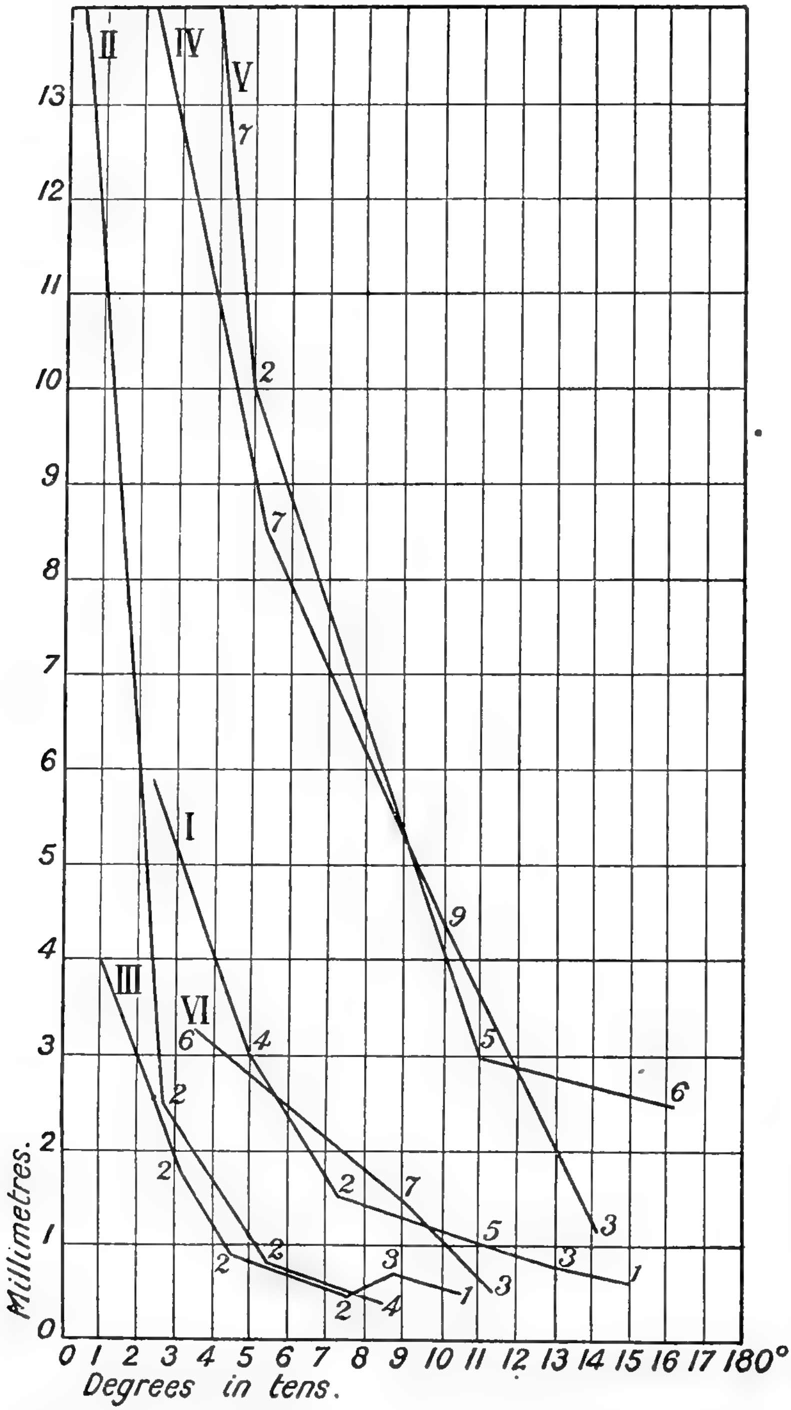
Amplitudes.—For seventeen large earthquakes the average amplitudes measured in millimetres were as follows: Shide, 2·1; Bidston, 1·4; Edinburgh, 1·4; and Kew, 1·5. Three of these are distinctly comparable.

1. *Decrease in Amplitude.*

As illustrative of the decrease in amplitude six large earthquakes have been selected from the catalogue of earthquakes recorded in the Antarctic regions in the years 1902–3. This catalogue is now being published. The dates and origins of the selected disturbances are the first six given on page 72. At distances varying between 30° and 165° from the above origins, records were made of each of these earthquakes at many stations. The actual number of observations are given on page 72. The instruments used were in all cases Milne horizontal pendulums. The amplitudes in millimetres in relation to distances from origins measured in degrees are shown in fig. 2. The small figures on a curve indicate the number of stations at or near given distances from an origin which were used to compute an indicated amplitude; thus for earthquake No. I., at a distance of 25° from its origin, *one* station gave an amplitude of 5·8 mm. At about 50° the average amplitude for four stations was 3mm., &c.

[1] See *Brit. Assoc. Reports* for 1901, p. 48, and 1903, p. 82.

FIG. 2.
Curves of Amplitude from Milne H.P.



Curves for earthquakes I., II., III., and V. show that up to a certain distance from an origin, amplitude is inversely proportional to distance.

After this the curves for amplitude rapidly become less steep and tend to be asymptotic to the ordinate for distance. The distance from an origin at which a curve tends to be asymptotic is apparently dependent upon the intensity of the originating impulse, which may be estimated by the magnitude of the records near to an origin and the distance at which effects of the impulse have been recorded.

The rapid decrease in amplitude shown in the curves is probably in large measure due to the spreading out of the waves as they approach their equatorial region, and also to frictional resistance. An estimate of this latter factor has been made by Dr. C. G. Knott. The data on which the estimate is based will be found in the chapter on Seismic Radiations in his forthcoming work on the Physics of Earthquake Phenomena. By a comparison of the maximum amplitudes of the records of an earthquake produced at any one station, as the tremors have passed through the minor arc or through the major arc connecting the epicentre with the station, he found that, in virtue of viscosity of the material, the amplitude of the Large Waves is cut down to half its amount at a distance of 41°·2.

Observations which indicate that certain earthquakes, although not recorded in their quadrantal region, but may be recordable in antipodean regions, suggest that the curves we have given would, if continued, have a slight rise upwards.[1]

2. *Changes in Duration.*

An indication of the value which may be placed upon a set of similar instruments as recorders of the duration of earthquakes which have originated at great distances, the following figures are quoted from the British Association Reports in 1901, p. 47; 1903, p. 82. For twenty-four large earthquakes recorded at Shide, Edinburgh, Bidston, and Kew, the total durations were respectively 1,493, 1,516, 1,464, and 1,371 minutes. The average durations of these earthquakes were therefore 62, 63, 61, and 57 minutes. These figures show that although the instruments at these stations were installed upon very different foundations, already described, the records they yielded were in close accordance. They also tend to confirm the idea I have frequently expressed—viz., that with megaseismic movements the crust of the world moves much in the same way as a raft does upon the ocean. All parts of it, whether alluvium or crystalline, respond to forced oscillations. For a small earthquake, by which is meant one which only disturbs a small area, the result is different. In this case stations in close proximity to each other may yield records of duration and amplitude which, amongst other things, depend upon the nature of the strata upon which the instruments have been installed. If a list is made of the duration of local shocks, and this is combined with a list giving the duration of teleseismic movements, it would appear that the duration of earthquakes increases with the distances of their origins. Such a result, however, is based upon records which are hardly comparable—one is a vibration of the earth's crust, whilst the other, to a great extent at least, appears to be due to a mass movement in the material beneath the crust. Attention was drawn to this in a British Association Report, 1892, pp. 225-227. In that report I expressed the view that both types of disturbance as they radiated exhibited a duration which became less and less. Now that we have many records of durations for given large earthquakes, which were obtained at widely separated stations,

[1] *Proc. Roy. Soc.*, Vol. A76, 1905, p. 293

the statement made nine years ago, so far as it relates to megaseisms, requires modification. In many instances it appeared that as a given world-shaking earthquake travelled away from its origin, there had been an increase in its duration. The matter seems to be of sufficient interest to demand close examination. This was undertaken by Mr. H. C. O'Neill, and the results at which he arrived are as follows :—

'The difficulty in attacking this problem plainly emerged when a number of earthquakes had been plotted on squared paper, with distance and duration as ordinates and abscissæ respectively. It is known that earthquake motion starts from (what may be regarded as) a point, and that it communicates its motion to distant parts of the earth's surface. At times the intensity of the shock is not sufficient to send waves as far as the antipodes of the centrum. We have therefore a point whence the motion starts and a point beyond which it is not recorded ; and as the latter has zero duration, it seems probable that the former has the maximum duration, and that the durations grow less as they approach the zero position. It was with the object of testing this inference that the investigation was commenced. The "Katalog der im Jahre 1904 Registrierten Seismischen Störungen," published by the Central Bureau of the International Seismological Association, offered the material ready made. Twenty-six earthquakes were taken from Liste A, giving 991 observations in all. Several of these were plotted on squared paper, but the curves were too irregular to yield any satisfactory conclusion, and an attempt to delete the most irregular observations offered too much opening to unconscious selection. Professor Pearson's method[1] for deriving correlation between two variables was therefore selected in order to avoid this. But it was necessary to secure a large number of comparable observations. Taking the mean of all the observed durations for a given earthquake, it is clear that the durations of different earthquakes are not comparable as they stand. The means for several earthquakes (in minutes) were 108·7, 94·13, 56·66, 52·42, 86·96, 67·62, 29·11, 49·62, 93·0, 199·2 ; and these show with sufficient clearness the point suggested. Some method was therefore required to obtain figures that should be more or less independent of any given earthquake. The readiest and simplest method that seemed to achieve this (suggested by Professor Pearson) is as follows: if x be the duration of a given earthquake at a given distance d, and if $\bar{x}$ be the mean of all the observed durations for the same earthquake, then the new duration character X at the given distance d is given by

$$\frac{x-\bar{x}}{\bar{x}} = \frac{x}{\bar{x}} - 1.$$

Since -1 is common to all, it may be neglected for calculating the correlation when X for distance $d = \frac{x}{\bar{x}}$. The 991 observations treated by this method were then arranged for correlation, when the result was ·06, with the probable error $\pm$ ·02. This means that if 1 represents perfect correlation and 0 complete absence of it, then ·06 represents the degree of correlation between distance and duration. And the result is to be interpreted as showing that the correlation is very small, but may be just significant, as it is three times the probable error ; or, that the

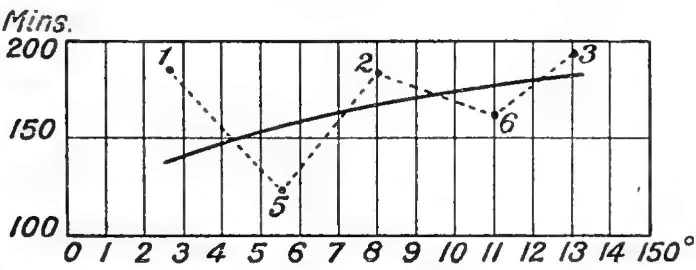
[1] A good account of this method and the nature of problems it is designed to treat is to be found in *Frequency Curves and Correlation*, by W. Palin Elderton.

variants are sufficiently numerous to render a larger correlation non-emergent.

'A tabulated list was then made of the stations which stood out, on the curves plotted originally, as abnormal—*i.e.*, those that stood at the head of very steep gradients when the points representing the observations were joined; such observations represented in numbers 2 to 4 $\bar{x}$. A list of these showed that the results from six stations were consistently abnormal at whatever distance from the origin they might be situated in different earthquakes. These stations were Irkutsk, Taschkent, Dorpat, Nikolaiev, Potsdam, and Hamburg, and they were accordingly deleted as representing a negligible variant. The curves were not much improved by this treatment, however, and so the correlation was re-calculated. This time thirty-one earthquakes were taken from Liste A in the Katalog, six from "Earthquakes and other Earth Movements recorded in the Antarctic Regions, 1902–3" (Royal Society—in press), and the Great Indian Earthquake of 1905 from Part II. of the report (Earthquake Investigation Committee, Tokyo, 1907). These gave 1,029 observations in all, and the correlation came out as ·10, with the probable error ± ·02, a more significant correlation.'

The next step in the investigations was to plot the duration of a given earthquake as recorded at stations situated at different distances from an origin upon squared paper. This was done for twenty-two disturbances, the distances of stations from origins varying from between 20° and 160°. The resulting curves or figures were, as might be expected, serrated in appearance (see dotted line, fig. 3), but still the greater number of them suggested that duration increased as the distance from the origin increased.

FIG. 3.



Degrees in tens.

No. 1, March 28, 1902. Shide List, No. 601.
Origin Banda. Nineteen observations.

When a number of stations at approximately the same distance from an origin were taken in groups and a mean time for each group was plotted against a mean distance an increase of duration with distance became more pronounced. The general trend or approximate curves for the first twelve of these figures is shown in fig. 4. The meaning of line No. I., for example, is that this earthquake at a distance of 25° from its origin had a duration of 135 minutes, while at 130° distant the duration was about 178 minutes. It is identical with the thick line shown in fig. 3. These durations are those indicated on seismograms *plus* the time taken for preliminary tremors to travel from an origin to the observing stations. Whether this correction is or is not necessary, because it is small, its effect upon the general result is small also. For four of the earthquakes, Nos. II., III., XI., and XII., the duration at the commencement and at the end of the movement is practically the same. It cannot be said to be less. For the remainder the duration at the end is distinctly greater than near the beginning. The greatest duration has generally been in regions lying between 70° and 110° from an origin; that is to say, in a quadrantal region where amplitude is least and approaches a constant value.

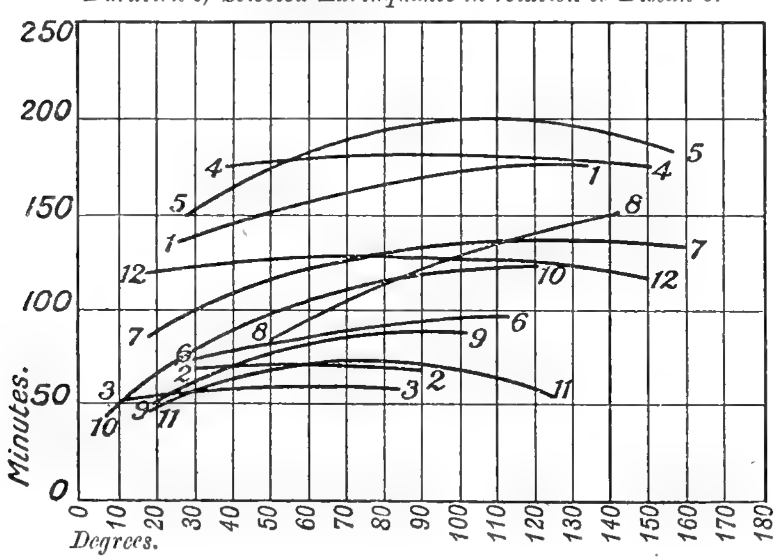
The following is a list of the twelve earthquakes employed, with their origins and the number of observations which were used in determining each curve :—

No.	Date	Shide No.	Origin	No. of Observations
1	March 28, 1902	601	Banda	19
2	May 2, 1902	607	N.E. Japan	8
3	May 8, 1902	609	N. of Philippines	13
4	Sept. 22, 1902	641	Guam	22
5	Sept. 23, 1902	642	Guatemala	20
6	Nov. 21, 1902	659	Formosa	24
7	Jan. 20, 1904	806	Costa Rica (?)	35
8	March 19, 1904	826	29° S. 71° W. (?)	26
9	March 31, 1904	832	95° E. 40° N.	35
10	April 4, 1904	834	23° E. 41° N.	28
11	April 5, 1904	835	102° E. 30° N.	27
12	Aug. 24, 1904	884	Philippines	43

For Nos. 1–6 only records from Milne instruments were employed. For the remainder the records were obtained from stations for the most part employing Milne instruments, but not in all cases. One explanation

FIG. 4.

Duration of Selected Earthquakes in relation to Distance.

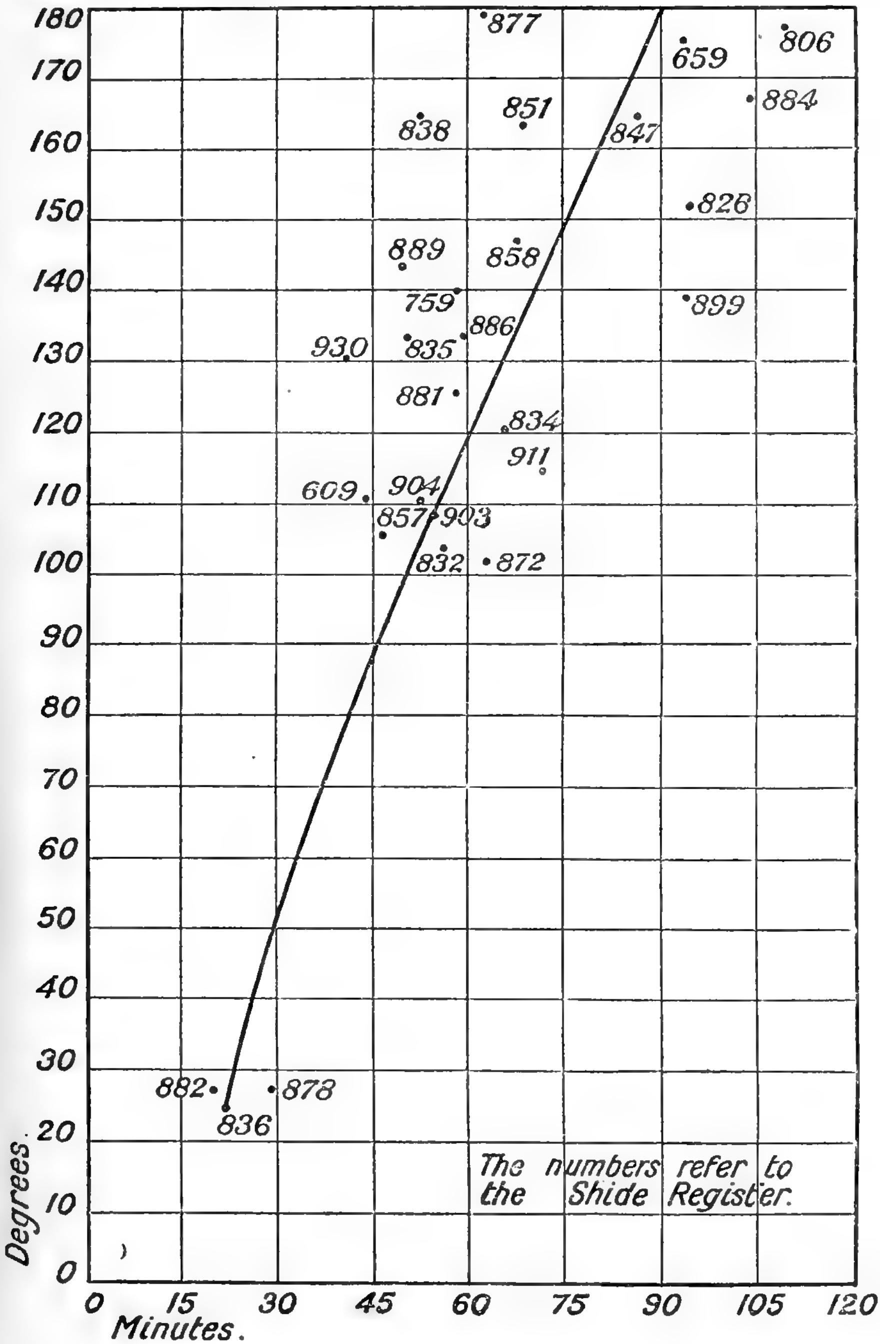


for the observations which have been made upon amplitude and duration is that at the time of a very large earthquake the material inside our earth is moved as a whole.

Fig. 5 indicates that the mean duration of an earthquake increases with the distance to which it is propagated. This in turn is dependent

Fig. 5.

Mean Duration of several Earthquakes and the Distance they have travelled.



upon the intensity of the initial impulse. Fig. 4 leads to similar conclusions.

VII. *On the Direction in which Earthquake Motion is most freely propagated.*

We frequently see the isoseists of an earthquake in the form of ellipses, which indicate that motion of a given intensity has been propagated farthest in a particular direction. In a discussion of earthquakes observed in the Antarctic regions, see 'Proceedings, Royal Society,' Vol. A76, 1905, p. 293, I showed that certain large earthquakes had travelled round the world in bands, the length of which had their greatest extension from their origins in particular directions. The object of the present note is to show that certain large earthquakes with approximately known origins in the Northern Hemisphere have been recordable at a greater distance measured towards the west than towards the east. Also the distance to which the motion extended across and to the south of the equator was less than the distance to which it travelled east or west in the Northern Hemisphere. The phase of motion here referred to is that of the large waves which travel to greater distances than their precursors. This particular phase has a practically constant speed, whether its path is across the alluvial plains of Asia, the granites of North America, or beneath an ocean. The crust of the world is apparently influenced by movement in a medium which it covers. The number of earthquakes considered has been seventy-four, and they are designated by their Shide number given in the registers published by the British Association. Their origins were in one of the following three districts :—

District No. 1 is south of the Caucasus, approximately 40° N. lat. and 45° E. long. The earthquakes considered are 588, 595, 598, 704, 705, 713*b*, 948, 1,077, 952, and 1,351.

District No. 2 is north of Eastern India, approximately 80° E. long. and 30° N. lat. The earthquakes considered are 618, 613*b*, 663, 626, 640, 644, 662, 632, 653, 676, 696, 692, 689, 793*c*, 720, 684, 679, 832, 833, 982, 1,070, 1,052, 1,036, 1,038, 963, 9,83*b*, 1,044*b*, 1,320, 1,293, 1,184, 1,133, 1,240, 1,208, 1,135, 1,264, 1,167, 1,129, 1,153, 1,468, and 1,475.

District No. 3 is east coast of Japan and north of the Philippines, approximately 130° E. long. and 30° N. lat. The earthquakes considered are 899, 896*b*, 935, 1,150, 857, 963, 1,166, 1,145, 1,387, 861, 859, 860, 863, 1,111, 1,266, 858, 903, 1,010, 1,274, 1,116, 1,130, 1,163, 1,386, and 862.

In the following three tables which refer to these districts we find in the successive columns—1st, the names of stations where earthquakes were recorded ; 2nd, the approximate distance of a station from an origin ; 3rd, the number of earthquakes which we should expect to have been recorded ; 4th, the number of earthquakes which were actually recorded ; 5th, the percentage of possible records. Stations the names of which are printed in italics are in the Southern Hemisphere.

In Great Britain there are five stations, and therefore the opportunities for obtaining records have been greater than they were at isolated stations. This partly may explain the high percentage of records obtained in Britain. But if we reduce the number of records obtained in Britain to the number obtained at San Fernando in Spain, where there is only one instrument, the general result is but little altered. A similar remark applies to India, where there are three stations. In New Zealand there are two stations. In Manila the instrument is not of the Milne type.

District No. 1, *South of the Caucasus.*

Station	Distance	Possible Records	Actual Records	Percentage of Records
Beirut	10°	4	4	100
Cairo	16	7	2	28
British stations	32	10	10	100
San Fernando	38	10	8	80
Indian stations	38	10	6	60
Irkutsk	44	9	5	55
Mauritius	60	7	2	28
Japan	72	9	0	0
Batavia	74	10	2	20
Cape Town	75	10	3	30
Toronto	80	10	4	40
Victoria	88	10	4	40
Australia	98	10	2	20
Honolulu	115	7	2	28
Cordova	125	10	2	20
New Zealand	135	10	2	20

District No. 2, *North of Eastern India.*

Station	Distance	Possible Records	Actual Records	Percentage of Records
Indian stations	12°	40	38	95
Irkutsk	28	38	35	92
Beirut	36	23	16	69
Manila	38	17	11	61
Cairo	40	33	17	50
Batavia	45	40	30	75
Japan	50	32	14	45
Mauritius	55	31	14	45
British stations	62	40	39	97
San Fernando	70	40	25	62
Australia	70	40	17	42
Cape Town	85	39	16	41
Victoria, B.C.	95	40	24	60
Toronto	100	40	21	52
Honolulu	105	26	16	66
New Zealand	105	36	5	14
Cordova	155	28	7	24

District No. 3, *Japan and the Philippines.*

Station	Distance	Possible Records	Actual Records	Percentage of Records
Irkutsk	30°	22	17	77
Batavia	40	21	11	52
Indian stations	45	24	18	75
Honolulu	60	24	17	71
Australia	60	24	13	54
Victoria, B.C.	72	24	12	50
Mauritius	75	24	7	29
Beirut	78	22	14	64
New Zealand	82	24	4	17
British stations	88	24	24	100
Toronto	98	24	13	53
San Fernando	100	24	17	71
Cape Town	120	24	7	29
Cordova	165	24	5	21

From the above three tables, if we omit Batavia, it being near the Equator, we obtain the following results :—

In District No. 1 the five stations in the Southern Hemisphere have an average distance from an origin of 98°, and the average number of records has been 23 per cent. The remaining nine stations in the Northern Hemisphere had an average distance of 51°, while the average percentage of their records is 59.

For District No. 2 the average distance from an origin for five southern stations was 94°, and the average percentage of records was 33. The corresponding figures for the eleven northern stations are 58° and 68 per cent.

For District No. 3 the figures for the five southern stations are 100° and 30 per cent. The corresponding figures for the eight northern stations are 71° and 70 per cent.

The averages for the three districts taken together are for the southern stations 97° distance and 39 per cent. of records, while for the Northern Hemisphere we get 60° and 66 per cent.

When looking at the above three tables it must be remembered that amplitude of motion decreases rapidly with distance from an origin, and therefore too much stress should not be put upon the fact that stations in the Southern Hemisphere were at greater distances from origins than those in the Northern Hemisphere. On p. 77 we compare stations in the two hemispheres which are at equal distances from origins.

Comparison of Records obtained from Stations lying to the West of Origins with those which lie to the East. The Stations compared are approximately at the same Distance from the Origins considered.

DISTRICT No. 1.

Stations to West. Station	Distance	Percentage of Records	Stations to East. Station	Distance	Percentage of Records
San Fernando	38°	80	India	33°	60
Toronto	80	40	Batavia	74	20
Victoria	80	40	Honolulu	115	28
Average	69	53	Average	75	36

DISTRICT No. 2.

Station	Distance	Percentage of Records	Station	Distance	Percentage of Records
Beirut	36°	69	Mauritius	38°	61
Cairo	40	50	Japan	50	45
Average	38	59	Average	44	53

DISTRICT No. 3.

Station	Distance	Percentage of Records	Station	Distance	Percentage of Records
Beirut	78°	64	Victoria	72°	50
San Fernando	100	71	Toronto	98	53
San Fernando	100	71	Victoria	72	50
Average	93	69	Average	78	51

The general average for the three districts combined is for the western stations a distance of 66° and 60 per cent. of records; whilst for the eastern stations the distance is also 66°, but the number of records fall to 46 per cent.

These figures, whether taken collectively or as entries for any pair of stations, apparently indicate that earthquake motion is propagated more freely towards the west than it is to the east.

Comparison of Records obtained from Stations in the Northern Hemisphere with those obtained in the Southern Hemisphere. All Stations which are compared are at approximately the same distance from the Origins considered.

DISTRICT No. 1.

Stations in Southern Hemisphere. Station	Distance	Percentage of Records	*Stations in Northern Hemisphere.* Station	Distance	Percentage of Records
Cape Town	75°	30	Toronto	80°	40
Australia	98	20	Victoria	88	40
Cordova	125	20	Victoria	88	40
New Zealand	135	20	Honolulu	115	28
			Honolulu	115	28
Average	108	22	Average	97	34

DISTRICT No. 2.

Station	Distance	Percentage of Records	Station	Distance	Percentage of Records
Mauritius	55°	45	Japan	50°	45
Australia	70	42	San Fernando	70	62
Cape Town	85	41	Victoria	95	60
New Zealand	105	14	Honolulu	108	66
			Toronto	100	52
			Victoria	95	60
Average	79	35	Average	86	57

DISTRICT No. 3.

Station	Distance	Percentage of Records	Station	Distance	Percentage of Records
Australia	60°	54	Honolulu	60°	71
Mauritius	75	29	Victoria	72	50
New Zealand	82	17	Victoria	72	50
Cape Town	120	29	Beirut	78	64
			Beirut	78	64
			British stations	88	100
			San Fernando	100	71
Average	88	32	Average	78	68

If we take an average for the above three districts we get for the Southern Hemisphere an average distance of 90°, with an average percentage of records of 29 per cent. For the Northern Hemisphere the corresponding figures are 87° and 53 per cent.

General Conclusions.

The General Conclusions are, *first*, that a greater percentage of earthquakes travel farther west, or against the motion of the earth, than they do towards the east; and *second*, that the range of recorded motion across the Equator to the south is shorter than it is towards the east or west.

In any hypothesis to explain these observations we should bear in mind that the direction in which a given earthquake travels farthest will involve, amongst others, the following considerations:—

1. What was the direction in which a given initial impulse was delivered? If the seventy-five earthquakes we have discussed all

originated from faults which ran north and south and haded to the west, which, however, is not likely, we should have a complete explanation of what has been noted.

2. Has the direction in which a primary impulse was delivered been southwards towards the Equator, or in the direction of the latitude of its origin?

3. Have the wave paths been sub-oceanic or sub-continental? In the first case we have a 'tapping off' of energy by a layer of water, and in the second by a layer of air.

4. The wave movement we are considering has been recorded upon the upper surface of the crust of our earth. To what depth beneath this covering does this movement extend? Are we dealing with a movement which is merely superficial or one which extends to a considerable depth in the material beneath the crust? Are the factors which govern wave speed within our earth the same in all directions?

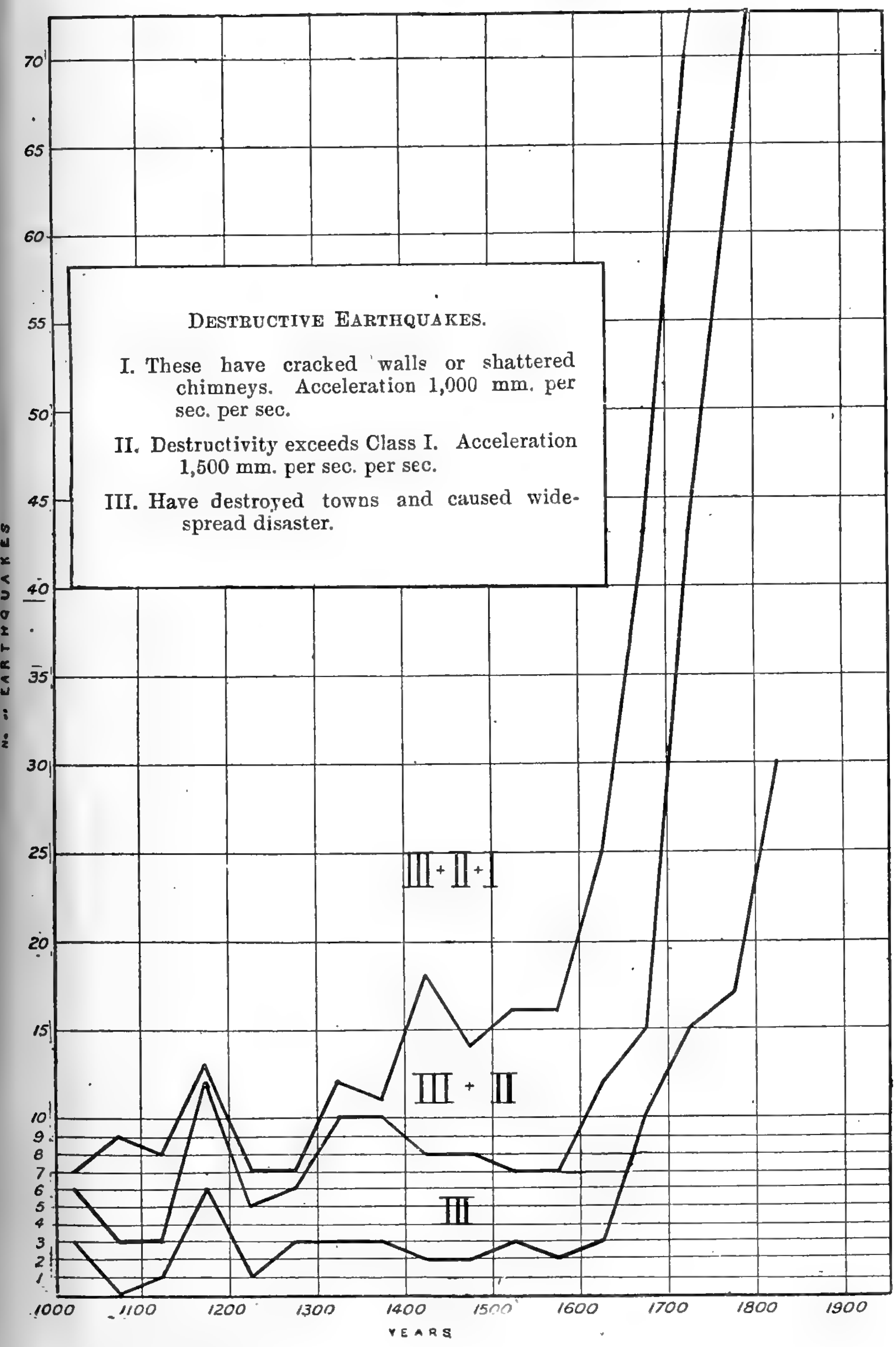
VIII. *A Catalogue of Destructive Earthquakes.*

(Still in preparation.)

The catalogue to which I wish to draw attention only refers to earthquakes which have caused structural damage. The earthquakes which are marked I. are those which have had an intensity sufficient to crack walls or break chimneys. This implies that the acceleration or rapidity of change of motion may have been about 1,000 mm. per second, and the destructivity has usually been confined to a single town or village. Those which are marked II. have had a destructivity so far in excess of Class I. that a few buildings have fallen. For this class the acceleration may be about 1,500 mm. per second, and the area may be represented by a radius of twenty miles. Class III. refers to earthquakes which have destroyed towns or caused widespread disasters. Although these earthquakes have occasionally been local, it is usually found they have been severe 50 or 60 miles round their origin and have produced effects similar to those of Class I. at distances of 200 or 300 miles. It is clear this classification is imperfect; certain earthquakes under Class II. might be included in Class III., whilst others under the head of Class I. might be included in Class II. It is, however, probable there are few mistakes about the entries in Class III. Earthquakes which have been described as slight or feeble, which have wakened up a few people, which have even rattled or broken a few windows, moved furniture, or have been simply described as being very violent, are altogether excluded from the catalogue.

The object of compiling a register of this sort is that it will be more uniform in its character and more nearly up to date than its predecessors. If we turn to large earthquake catalogues which have hitherto been published, as, for instance, those of Mallet and Perrey, in the first place we notice that the material they contain is very heterogeneous in character, and the heterogeneity is variable in different periods. The earlier records they give refer to earthquakes which have devastated districts, or to Class III., whilst as we approach modern times equivalent disturbances are eclipsed by a large number of tremors which have not been sufficiently intense to be included even in Class I. Another factor which tends to disturb the uniformity of the older earthquake registers is the fact that the entries in the same increase in number with the spread of civilisation. For example, records of earthquakes greatly increased about 100 years

Fig. 6.


Destructive Earthquakes.
I. These have cracked walls or shattered chimneys. Acceleration 1,000 mm. per sec. per sec.
II. Destructivity exceeds Class I. Acceleration 1,500 mm. per sec. per sec.
III. Have destroyed towns and caused wide-spread disaster.
III + II + I
III + II
III
No. of Earthquakes
Years
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
70
65
60
55
50
45
40
35
30
25
20
15
10
9
8
7
6
5
4
3
2
1

after the discovery of the two Americas. To this we may add that it has only been of late years that the records of certain countries with an ancient civilisation have become accessible to us. Up to the year 1850 Europe imagined that in Japan there were from one to six earthquakes per year. Now we know there are at least 1,000. We also know that the Japanese have for a long time past published 'Jishin-Nendaiki,' or earthquake calendars, which give records of very destructive earthquakes since extremely early times.

As an illustration of the difference between the new catalogue and the one published by Mallet, who endeavoured to exclude from his registers very small disturbances—such as 'after-shocks'—I find that between 1800 and 1808, which are years taken at random, Mallet gives 407 entries, but of these only thirty-seven are stated to have produced structural damage. All other large catalogues appear to be of the same nature. Large earthquakes which have announced changes of geological importance in the earth's crust stand side by side with great numbers of seismic trivialities, many of which may not even have rattled a window. To give each unit in such collections an equal value, and this has frequently been the case, would not for many analyses lead to satisfactory results. For example, the old catalogues when taken *en bloc*, could hardly be expected to give us accurate information about the distribution of seismic energy in time.

The sources from which material has been obtained to form the present catalogue are various. From A.D. 15 to 1842 I am indebted to Mallet's catalogues, from that date to 1864 I have in great measure relied upon Alex. Perrey. Some of his writings, however, appear to be only in MS., and therefore have not been accessible. To obtain records of the last forty-three years, however, has been a matter of considerable difficulty. Appeals to daily journals like the 'Times' have proved to be very disappointing. For example, the records of large earthquakes in the 'Times' for 1855 and 1864 were respectively five and one, while references to foreign journals and the Transactions of learned societies show that very destructive earthquakes occurred in each of those years from twenty-seven to thirty times.

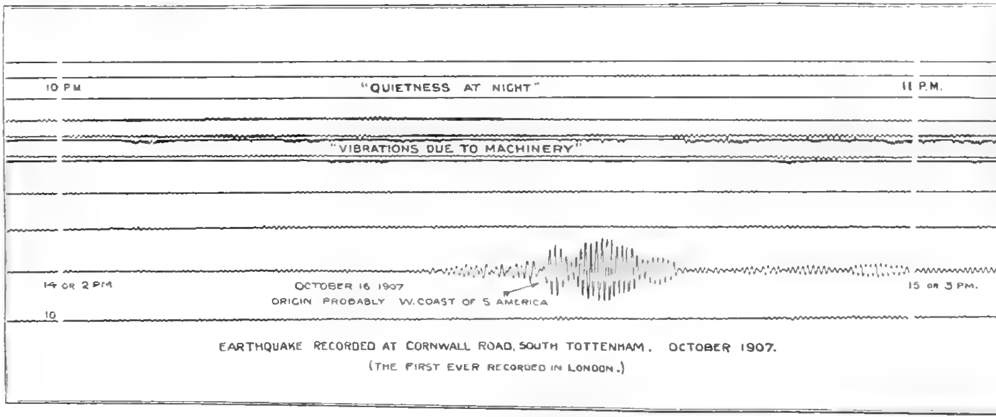
If this catalogue proves to have more homogeneity in its character than its predecessors, it is to be hoped that analyses of the same will lead to more definite results than have hitherto been obtained from earthquake statistics.

An addition to this work is a Catalogue of Chinese Earthquakes. It has been compiled by my assistant, Mr. Shinobu Hirota, and, so far as I am aware, it is the most important collection of records relating to earthquakes in China which have appeared in a European language.

As an illustration, and also as an introduction to analyses which may be made from a catalogue of destructive earthquakes, I give the following :—

On the Seismicity in Europe and adjacent Countries between the Years A.D. 1000 *and* 1850.

The subjoined table shows the number of very destructive earthquakes which have been recorded between A.D. 1000 and 1850. The grouping is in periods of fifty years. Under the heading marked III. we have the number of exceedingly destructive earthquakes, the records



Illustrating the Report on Seismological Investigations of which it is assumed have not been lost to history or tradition. In the next column we find the sum of earthquakes of values III. and II., whilst in the last column is given the sum of earthquakes having an intensity of Classes III., II., and I. The destructivities of Classes I., II., and III. have already been defined.

—	III.	II. + II	III. + II. + I.
1000–1050	3	6	7
1050–1100	0	3	9
1100–1150	1	3	8
1150–1200	6	12	13
1200–1250	1	5	7
1250–1300	3	6	7
1300–1350	3	10	12
1350–1400	3	10	11
1400–1450	2	8	18
1450–1500	2	8	14
1500–1550	3	7	16
1550–1600	2	7	16
1600–1650	3	12	25
1650–1700	10	31	42
1700–1750	15	43	70
1750–1800	17	87	169
1800–1850	30	90	202

These figures are also shown as three curves (fig. 6). An inspection of these will show that they have a striking similarity. Between the years 1150 and 1250 each indicates an increase in seismic activity during that period. The next increase commences about the year 1650, since which records even of the most destructive type of earthquake have during successive periods each of fifty years rapidly increased in number. Inasmuch as all these records refer to a European area, it is difficult to imagine that the great increase in numbers from the middle of the seventeenth century should be accounted for by a sudden stimulus to keep better records from that period. Earthquakes of Class III. may be regarded as events of historical importance; and, if this is so, it would seem that records of the very destructive disturbances between A.D. 1300 and 1600 should approximate in their correctness to those which occurred subsequently to the latter date. My own idea is that about 1650 there was a very marked increase in seismic and, I may add, volcanic activity. Whether this has any connection with the observations of geologists or those who study magnetics or other branches of earth physics must be left for their consideration.

IX. *On a Seismogram obtained in London on October* 16, 1907.

The accompanying seismogram, Plate II., was recorded in the engineering workshops of Mr. R. W. Munro, South Tottenham, where an instrument had been set up for examination before shipping for South Australia. Vibrations due to machinery are marked, while at night the instrument yielded a fairly straight line. This steadiness at night, notwithstanding casual traffic, suggests that a seismograph might find a sufficiently steady site in a London square or park. The seismograph is identical with those first adopted by the British Association, the record-receiving surface, however, instead of only moving at 60 mm. per hour now moves at four times that rate. Because the paper is on a cylinder and not used as a band, about half the quantity of film is employed, an open scale is obtained, and in many cases, owing to the absence of halation due to long exposure, the Shide Registers, as published by the British Association, show that earlier commencements are obtained. With the present receiver, it is distinctly the most satisfactory instrument with which I have had any experience. Its value as a recorder of minute tremors is indicated on p. 64. For a description of the instrument see British Association Report, 1904, p. 44.

X. *Map of the World.* *By* R. D. Oldham.

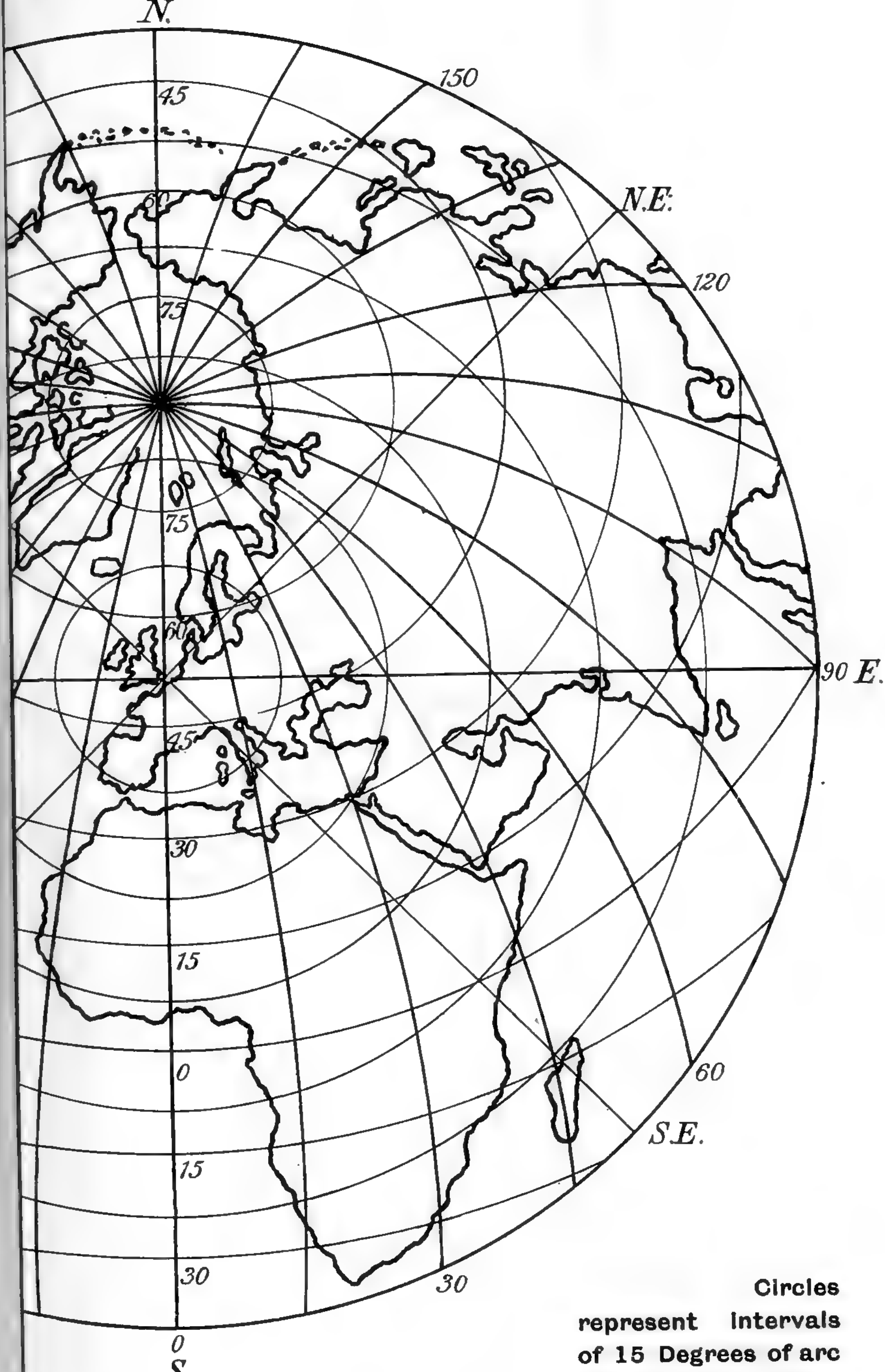
The accompanying map of the world, Plate III., was made by Mr. R. D. Oldham for certain purposes of his own, but as it was thought it might be of general use to seismologists we have, with his consent, added it to this report. Mr. Oldham describes the map as follows :—

'The map is constructed on the zenithal projection, with Greenwich as the centre. All great circles passing through the centre of the map are represented by straight lines, and equal distances measured along these great circles on the surface of the earth by equal radial distances on the map. Meridians and parallels of longitude and latitude are drawn at intervals of 15°, and intervals between the concentric circles represent intervals of 15° of arc, or an average linear distance of 900 nautical miles, or 1,667 kilometres. For convenience, and to avoid excessive distortion, the whole surface of the earth is divided into two hemispheres ; in the one, distances are to be measured directly from the centre outwards, in the other they are measured from the circumference inwards, and added to the length of the radius of the map. This represents one quarter of the circumference of the globe. The direction of the straight line drawn from any point to the centre of the map gives the azimuth of the great circle at Greenwich. The map may also be used for obtaining the distance between any two points situated on the same great circle with each other and Greenwich, but cannot be used with accuracy for measurements between two points not so situated.

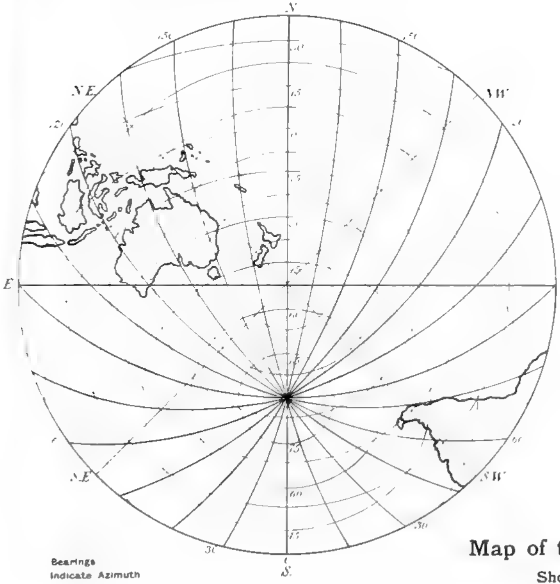
'Though constructed to Greenwich as a centre, it can be used with sufficient accuracy for many purposes for any place in the British Isles or the nearer parts of Europe.'

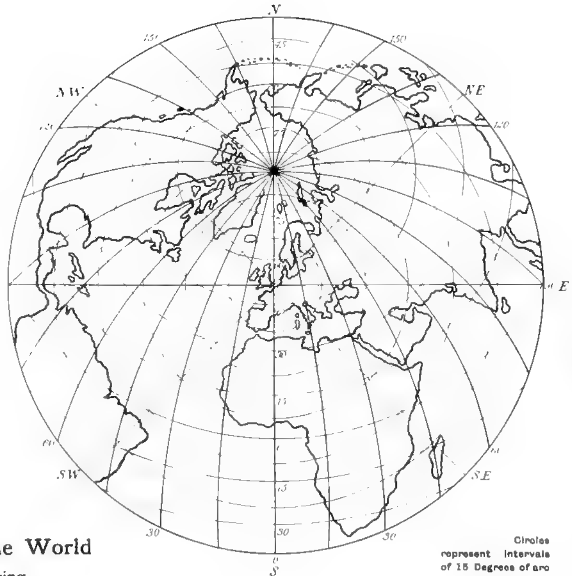
XI. *A Catalogue of Chinese Earthquakes.* *By* Shinobu Hirota.

In May 1839 Ed. Biot presented to the Académie des Sciences a 'Catalogue Général des tremblements de terre, affaissements et soulèvements de montagnes, observés en Chine depuis le temps anciens jusqu'à nos jours.' This was published in the 'Annales de Chimie et de Physique,' tome ii. 1841, p. 372. It contains references to about 480 earthquakes. In the twenty-ninth volume of the Reports of the Imperial Earthquake Investigation Committee, 1899, Dr. F. Ōmori gives a Catalogue of Chinese Earthquakes. It is printed in Chinese ideographs, and the characters he uses are apparently those in the works from which he quotes. Both M. Biot and Dr. Ōmori quote from the Chinese author Ma-touan-lin, who made a catalogue of earthquakes and the historical annals called Thoung-kien-khang-mou. Dr. Ōmori has also referred to other Chinese histories. By combining these two catalogues one result is that the 480 entries in M. Biot's catalogue is now extended to 889,



Circles represent intervals of 15 Degrees of arc (about 1,036 miles.)





Bearings indicate Azimuth from Greenwich.

Map of the World
Showing
Distance and Direction
from
Greenwich.

Circles represent intervals of 15 Degrees of arc (about 1,036 miles.)

the greater number of which are to be found in the catalogue of Dr. Ōmori. The 324 which are common to both, and which refer to the same events, we should expect to find strictly identical, but this is not the case. For example, the names of provinces and places are frequently different. In certain instances this has apparently resulted from the use of old names rather than modern ones. This difficulty was not overcome until we received from Japan a series of fourteen maps which show the various changes which have taken place with regard to the provinces and the names of places since very early times. Another striking difference between these two catalogues is the differences in dates. The dates I prefer to use are those given by Dr. Ōmori. The reason for doing this is that in Japan we are familiar with the Chinese lunar chronological system, and also that tables have been compiled which give the European equivalent of Chinese dates. In cases where differences in dates have exceeded a few days both dates have been given. The first date is a translation of ideographs used by Dr. Ōmori.

Mallet, in his large catalogue of earthquakes published by the British Association in 1852, 1853, and 1854, makes but few references to seismic disturbances in China. When we think of the enormous labour he spent upon the collection of statistics relating to this work, it is difficult to understand how the registers brought together by Biot had escaped his attention.

In the 'Archives des Sciences Physiques et Naturelles,' April 1899, F. de Montessus de Ballore gives us a general description of the distribution of seismic activity in China. However, he does not give us a catalogue of earthquakes. The map which accompanies his paper is based upon the records of Biot and a catalogue by Mouchketoff and Orloff of the earthquakes in the Russian Empire. In the 'Trans. Seis. Soc. Japan,' vol. x. 1887, there is a short Paper on earthquakes in China by Dr. Macgowan. Unfortunately Dr. Macgowan's list of earthquakes was nearly all destroyed by fire, and therefore he is only able to speak in general terms. One curious remark about tremors which were experienced in Chekiang, Kiangsu, and in the western regions is that they are followed by the appearance on the ground of substances which in Chinese books are styled 'white hairs several inches in length, like horse-tail hair.' Dr. Macgowan's impression is that the regions where these appear are all, or nearly all, in alluvial valleys.

Crystallisation of exhalations may be curious, but in making this translation I have met with notes which are equally remarkable. In the fourteenth century the names of two towns, Pingyang and Taiyuan, were changed to Chinning and Chining. This alteration was made by imperial decree with the hope that earthquakes, which had so frequently visited these places, would, as the result of the change, be reduced in their numbers.

In addition to the translation a map has been drawn, on which earthquake centres are indicated. From this we see that earthquakes have been most frequent in the north of Peking, the extreme north of Kansu, along the course of Hoang-Ho, where it divides the provinces of Honan, Shensi, and Shansi, around Nanking, on the coast of Fu-Kiang, and in the centres of Yunnan and Ssuchuan. The high frequency along the Hoang-Ho, particularly at its two great bends, which are respectively near to the Peling Mountains and the Ala Shan Mountains, suggests that the sudden changes in the trend of a valley may be connected with rock-folding, which from time to time has been accompanied with rock-fracture. No records are given for the extreme west of China or for Mongolia. In all probability this means that these districts were in past time as sparsely inhabited as they are at present. We now know that to the west of China, in Tibet, large earthquakes occur very frequently. I believe this to be the first time that anything approaching a complete catalogue of Chinese earthquakes has appeared in a European language.

Catalogue of Chinese Earthquakes.

B = statement in Biot's 'Catalogue.' The names of provinces are in *italics*.

	Year. B.C.		
1	1820		Mount Taishan, Chinan, *Shantung*. Shock.
2	1155		Fenghsiang Fu, *Shensi*.
3	618		Ditto
4	557		Ditto
5	523		Ditto
6	519		Ditto
7	492		Ditto
8	466		Taiyuan Fu, *Shansi*. It lasted seven days, and many killed.
9	233		Earthquake.
10	193	Jan.	Great earthquake, Lunghsi, Kungchang Fu, *Kansu*. More than four hundred houses were destroyed.
11	186	Jan.	A great earthquake took place at Wutu, south-east of Lunghsi, Kungchang Fu, *Kansu*. The face of a mountain slipped down and about 760 people were killed.
12	175	Feb.	Earthquake.
13	143	May.	Earthquake.
14	131	June.	Earthquake at Chengho, Chienning Fu, *Fuhkien*. Many people killed.
15	88	Aug.	Earthquake.
16	72		South of Yellow River, Honan Fu, *Honan*.
17	70		A great earthquake took place from Honan Fu, *Honan*, to Pehhai in Laichou Fu, *Shantung*. Forty-nine prefectures were damaged. More than six thousand killed.
18	68	Sept.	A great earthquake, Lunghsi, Kungchang Fu, *Kansu*, in which many castle walls, temples, and houses were destroyed; about six thousand people were killed.
19	67	Oct. 12.	Earthquake.
20	47	April 17.	Great earthquake at Lunghsi, Kungchang Fu, *Kansu*, and Loyang, Honan Fu, *Honan*. Many castle walls and temples were destroyed and many people were killed.
21	41		Earthquake.
22	39		Earthquake.
23	34		Earthquake.
24	30		Earthquake.
25	26	July 23.	A great earthquake took place at Kienwei, in Chiating Fu, *Ssuchuan*. Two mountains were displaced and the rocks fell into the river and changed its course. The ground did not come to rest for 21 days, and there were 124 shocks. Many castles, temples, and houses were destroyed, and about thirteen people were killed.
26	A.D. 7	Nov. 10.	Earthquake in the Imperial City, Changan (now Hsian), *Shensi*, and the northern district. It destroyed more than thirty castle walls, and 415 people were killed.
27	16	March	Earthquake Hsian Fu, *Shensi*.
28	46	Oct.	Earthquake in forty-two counties. Most damage was done at Nanyang, *Honan*; the ground opened and water burst out from the fissures, and many people were killed (B, 42 earthquakes).

No.	Date. A.D.		
29	76	April 25.	Earthquake at Tungping (Taian Fu), Shanyang, now Ye-chou Fu, *Shantung*.
30	92	Aug. 8.	Earthquake in thirteen counties and towns.
31	93	April 7.	Earthquake at Lunghsi, Kungchang Fu, *Kansu*.
32	95	Nov. 8.	Earthquake at the Imperial City, Loyang, Honan Fu, *Honan*.
33	96		Yiyang, Honan Fu, *Honan*.
34	97	April 7.	Earthquake at Lunghsi, Kungchang Fu, *Kansu*.
35	107		Eighteen counties and towns shaken (B, 18 earthquakes).
36	108		Twelve counties were shaken (B, 12 earthquakes).
37	110	Jan. 11.	Nine counties were shaken.
38	110	April 14.	Four counties were shaken.
39	111	Feb. 1.	Ten counties were shaken. (Date given by Biot is slightly different.)
40	113	Feb. 5.	18 counties were shaken.
41	113		18 ditto.
42	114		15 ditto (B, 15 earthquakes).
43	115	Dec. 11.	10 ditto.
44	116	March.	10 ditto.
45	117	Jan. 17	9 ditto.
46	117	Feb.	13 ditto (B, 13 earthquakes).
47	118		14 ditto.
48	119	March 9.	Earthquake at the Imperial City, Loyang, Honan Fu, *Honan*. It was felt over forty-two counties; the ground was cracked, many castle walls and houses were destroyed and many killed.
49	119	Winter.	Eight counties were shaken.
50	120		Twenty-three counties were shaken.
51	121	Oct. 8.	Thirty-five counties were shaken and towns damaged. The land was cracked, many castle walls and houses were damaged, and many people were killed.
52	122	June 21	Earthquake at the Imperial City, Loyang, Honan Fu, *Honan*, and in thirteen counties.
53	122	Oct. 23.	An earthquake in twenty-seven counties, and towns were shaken.
54	123		Earthquake at the Imperial City, Honan Fu, *Honan*, and in thirty-two counties (B, 32 earthquakes).
55	124		Earthquake at the Imperial City, Honan Fu, *Honan*, and in twenty-three counties (B, 23 earthquakes).
56	125		Earthquake at the Imperial City, Honan Fu, *Honan*, and in sixteen counties (B, 16 earthquakes).
57	128		Earthquake at the Imperial City and Hanyang, now Fuchiang, Kanchang Fu, *Kansu*. At Hanyang great damage was done, and many people were killed and water burst out from the ground.
58	133	June 18.	Earthquake at Imperial City, Loyang, Honan Fu, *Honan*.
59	136	Feb. 18.	Ditto.
60	137	May.	Ditto.
61	137	Dec. 21.	Ditto.
62	138	Feb. 28.	Earthquake at Imperial City and Chinching, Lanchou Fu, Lunghsi, Kungchang Fu, *Kansu*. Many castle walls and houses were destroyed and many people were killed.
63	138	June 2.	At the Imperial City, Loyang, Honan Fu, *Honan*.
64	139	April 28	Ditto.
65	140	April 2.	Ditto.
66	144	Feb.	A great earthquake took place at Liangchou Fu, *Kansu*, and six neighbouring districts; the ground did not come to rest from October last year to April this year, about 180 days. The land opened and mountains were displaced; many houses were destroyed and many people were killed.
67	144	Oct. 24.	Earthquake at Imperial City, Loyang, Honan Fu, *Honan*.
68	147	May 26.	Ditto.
69	147	Oct. 31.	Ditto.

No.	Date. A.D.		
70	149	Oct. 31.	Earthquake.
71	149	Nov. 11.	Earthquake. Same year fourth moon there were several earthquakes at six places.
72	151	Dec. 23.	Earthquake at the Imperial City, Loyang, Honan Fu, *Honan*.
73	152	Feb.	Ditto.
74	152	Dec. 11.	Ditto.
75	154	March 4.	Ditto.
76	156		Earthquake.
77	156	Aug.	Hotung (now Pingyang Fu, Puchou Fu), *Shansi*.
78	156	Dec.	Earthquake at the Imperial City, Loyang, Honan Fu, *Honan*.
79	161		Loyang, *Honan*, Fenghsiang Fu, *Shensi*, and Liangchou Fu, *Kansu*.
80	162	June 21.	Earthquake at the Imperial City, Loyang, Honan Fu, *Honan*.
81	165	Nov. 4.	Ditto.
82	167		Pingyu, Loyung (now Honan Fu), *Honan*, Kaoping, Tsechou Fu, *Shansi*.
83	171	April 3.	Earthquake in Hotung, Pingyang Fu, Puchou Fu, *Shansi*.
84	173	July.	Ditto.
85	177	Nov.	Ditto.
86	178	Mar. 26.	Ditto.
87	178	May 10.	Ditto.
88	179	April.	Earthquake at the Imperial City, Loyang, Honan Fu, *Honan*.
89	180	Jan.	A great earthquake at Chiuchuan, in Kanchou Fu, *Kansu*. The ground did not come to rest until spring next year. There were about eighty shocks. Water burst out from the ground, many houses were destroyed, and many people were killed.
90	191	July 30.	Earthquake.
91	194	July 6.	Ditto.
			[Between the years 195 and 225 no records were kept on account of the great Rebellion.]
92	225		Chiangtung (Nanking), *Kiangsu*.
93	234	Dec.	Loyang (Honan Fu), *Honan*. Many houses were destroyed.
94	237	June.	Chiangtung (now Nanking), *Kiangsu*.
95	237	July.	Loyang (Honan Fu), *Honan*, and Nanking. Many houses were destroyed.
96	239	Feb.	Two earthquakes.
97	241	Dec.	Nanan, Kungchang, *Kansu*.
98	242	Aug. 31.	Ditto.
99	243	Jan.	Wei district, Changte Fu, *Honan* (northern part of).
100	245	Mar. 31.	Nanan, Kungchang Fu, *Kansu*.
101	248		Chiangtung (Nanking), *Kiangsu*.
102	263		Shu (Chengtu), *Ssuchuan*.
103	264		Earthquake at Shu, comprising the west part of *Ssuchuan*. It was the Imperial residence. Now forming Chengtu.
104	269	May 18.	Earthquake.
105	271	April 3.	Earthquake, Loyang, Honan Fu, *Honan*.
106	276	Aug. 28.	Honan Fu, *Honan*; Hotung (comprising Puchou Fu, Pingting, Chiang, Ho, and Chieh) and Pingyang Fu, *Shansi* (B, July 6).
107	278	July 16.	Earthquake at Yinping Fu (now Lungan Fu), *Ssuchuan*, and Kuangwu, Ninghsia Fu, *Kansu*.
108	278	Aug. 2.	Earthquake at Yinping Fu (now Lungan Fu), *Ssuchuan*.
109	281	Mar. 15.	Earthquake at Huainan (now Ho), Taiping Fu, *Anhui*, and Tanyang (comprising Chenchiang Fu, *Kiangsu*, and *Anhui*).
110	284	April.	Earthquake at the Imperial City, Loyang, Honan Fu, *Honan*.
111	285	Aug.	Earthquake, Nanyung Fu, *Honan*.
112	285	Sept. 9.	Nanking, *Kiangsu*.
113	286	March.	A violent earthquake took place at Chushih (now Chengtu Fu, Chiating Fu), and Yinping, Lungan Fu, *Ssuchuan*. There was a great landslip, and many houses were destroyed. At Yingping a dam was destroyed.

No.	Date. A.D.		
114	286	Aug.	Earthquake at Kienwei and Nanan, in Chiating Fu, *Ssuchuan.*
115	286	Sept.	Earthquake at the Imperial City, Loyang (now Honan Fu), *Honan.*
116	287	June.	Earthquake at Kienan, Chienning Fu, *Fuhkien.*
117	287		Earthquake at Yinping, Lungan Fu, *Ssuchuan.*
118	287	Aug.	Earthquake at Tanyang (comprising Chenchiang Fu, *Kiangsu*, and Taiping Fu, *Anhui*).
119	288	Feb.	Earthquake at Kueichi (comprising *Chehkiang*, see Shaohsing Fu, the south of *Anhui*, and the north of *Fuhkien*), Tanyang, Taiping, *Anhui*, and Wuhsing (now Huchou Fu), *Chehkiang.*
120	288	June 7.	Earthquake at Changsha Fu, *Hunan*, Nanhai, Canton, Kuangchou Fu, and eight neighbouring districts, *Kuangtung.*
121	288	July-Aug	Earthquake. Four more shocks, and three of them accompanied by noise.
122	288	Oct.	Earthquake at Linho, Pingle Fu, *Kuangsi.*
123	289	Jan.	Ditto.
124	290	Oct. 6.	Earthquake in Tanyang, Taiping Fu, *Anhui.*
125	291	Jan.	Ditto.
126	291	Jan. 18.	Earthquake at Loyang (now Honan Fu), *Honan* (B, 292, January 18).
127	294	March.	Earthquake at Liaotung, *Shingking*, Shangku, Hsuanhui Fu, north of *Chihli*, and Shangyang, in Chingchou Fu, *Hupeh.*
128	294	June.	Earthquake at Shu, Chengtu Fu (comprising west part of *Ssuchuan*). A mountain was shaken down, water burst out from the ground, and many people were killed.
129	294	Sept.	Earthquake at Shangku, Hsuanhua Fu (comprising the north part of *Chihli*). The ground was fissured and water burst out from the cracks, and about 100 people were killed.
130	294	Nov.	Earthquake at the Imperial City, Loyang (now Honan Fu), *Honan.*
131	294	Dec.	Earthquake at Kaifeng and Nanyang, Kia. The whole of *Honan.*
132	295	Jan.	Earthquake at the Imperial City, Loyang, *Honan.*
133	295	June.	Earthquake.
134	295	July.	Earthquake at Chincheng, in Lanchou Fu, *Kansu.*
135	296	Mar. 12.	Earthquake.
136	298	Feb.	Earthquake at Ching, in Hochien Fu, *Chihli*, and Chenchou Fu, *Hunan* (B, March 6).
137	302	Jan.	Earthquake.
138	303	Dec.	Ditto.
139	304	Jan.	Ditto.
140	309	Nov.	Earthquake at Hsiangyang and Chingchou, *Hupeh.*
141	310	May.	Earthquake in Yenchou, *Shantung*, and Hsian Fu, *Shensi.*
142	314	May 6.	Earthquake.
143	315	July 23.	Earthquake at Changan, in Hsian Fu, *Shensi.*
144	318	May.	Earthquake at Hsiping, in Juning Fu, *Honan.* Water burst out. Same time at Kungchang Fu, *Kansu*, and Wuchang Fu, *Hupeh.*
145	319	Jan.	A great earthquake at Luling, in Chian Fu, Yuchang (literary name of *Kiangsi*), Wuchang, and Hsiling (now Yichang Fu), *Hupeh.* A mountain shattered and water burst out.
146	319	June.	Earthquake at Chishan, in Taiyuan Fu, *Shansi.* Great landslip, and many people killed.
147	320	May.	Earthquake at Tanyang, in Chenchiang Fu; Wu, in Suchou Fu; Tsinling (now Changchou Fu), *Kiangsu.*
148	327	March.	Earthquake at Chiangling, Chingchou Fu, *Hupeh.*
149	327	April.	Earthquake at Yichou, comprising parts *Yunnan* and Lungan Fu, *Ssuchuan.*
150	327	May 13.	Yuchou (now forming Taiping Fu, *Anhui*).
151	332	April.	Kueichi, comprising Huchou, *Chehkiang* (Shaohsing), Taiping Fu, *Anhui*, and the north of *Fuhkien.*

No.	Date. A.D.		
152	334	May 14.	Kueichi, comprising *Chehkiang*, the south of *Anhui*, and the north of *Fuhkien*.
153	345	Aug. 10.	Earthquake, Loyang, Honan Fu, *Honan*.
154	347	Jan.	Ditto.
155	347	Feb.	Earthquake, Kengcheng, Puchou Fu, *Shansi*.
156	347	Oct.	Ditto.
157	348	Nov. 18.	Ditto.
158	349	Feb. 17	Ditto.
159	353	Oct. 1.	At the Imperial City, Kienyeh or Nanking (now Chiangning), *Kiangsu*, accompanied by a noise like thunder.
160	354	Feb. 28.	Earthquake with a noise like thunder. Hens and pheasants cried before the earthquake.
161	355	May 12.	Earthquake.
162	355	June 3.	Ditto.
163	358	Dec.	Ditto.
164	361	Sept.	Liangchou Fu, *Kansu*.
165	362	May 24.	Earthquake.
166	363	May 19.	Yangchou Fu, *Kiangsu*. Water became muddy in ponds, which overflowed.
167	364	April 23.	Kiangling, Chingchou Fu, *Hupeh* (B, March 29).
168	366	March.	Liangchou, *Kansu*. Water burst out.
169	372	Nov. 24.	Ancheng (now Chian Fu), *Kiangsi*.
170	373	Nov. 19.	Earthquake.
171	374	March 1.	Ditto.
172	374	Aug.	Liangchou, *Kansu*. A mountain slipped down.
173	377	May 13.	Earthquake.
174	377	July 6.	Ditto.
175	386	July 22.	Ditto.
176	390	April 2.	Ditto.
177	390	Aug.	At the Imperial City, Pingcheng, Taiyuan Fu, *Shansi*, and Nanking.
178	391	Feb. 6.	Earthquake.
179	392	July 14.	Ditto.
180	393	Jan. 26.	Ditto.
181	393	Jan. 30.	Ditto.
182	393	Mar. 27.	Earthquake (B, March 2).
183	400	May 25.	Earthquake.
184	400	Oct. 10.	Ditto.
185	408	Mar. 1.	Earthquake. A noise was heard.
186	408	Nov. 7.	Earthquake.
187	409	Feb. 10.	Hsunyang (now Chiuchiang Fu), *Kiangsi*. With a noise like thunder.
188	412	Jan.-Ap.	Nankang Fu and Luling, in Chian Fu, *Kiangsi*. Shocks occurred four times a day.
189	414	April 25.	Earthquake.
190	420	Aug. 6.	Ditto (B, Sept. 10).
191	435	May.	Imperial City, Nanking, *Kiangsu*.
192	438	Aug. 10.	Earthquake.
193	458	May 27.	Ditto.
194	462	Aug. 23.	Earthquake, with a noise like thunder. Most damage was done at Yenchou, in Lu, comprising the south part of *Shantung*.
195	476	June	Earthquake.
196	477		Ditto.
197	499	Aug.	Earthquakes night and day till next year. Many small houses were destroyed.
198	507	Jan.	Kienyeh, now Chiangning Fu, *Kiangsu*.
199	522	Feb.	Kienkang, in Chiangning Fu, *Kiangsu*. Present name is Nanking (the Imperial City).
200	526	Jan.	Earthquake, Nanking, *Kiangsu*.
201	533	Feb.	Earthquake, Kienkang, *Kiangsu* (now Chiangning).
202	537	Nov.	Ditto.

No.	Date. A.D.		
203	537	Dec.	Earthquake, Kienkang, *Kiangsu* (now Chiangning).
204	541	March.	Ditto.
205	543	Feb.	Ditto.
206	546	Jan.	Ditto.
207	549	May.	Kienkang, two earthquakes.
208	558	June.	Earthquake at Kienkang, *Kiangsu* (now Chiangning).
209	563		Pinglieh, Chengte Fu, *Chihli.*
210	572	Nov.	Earthquake, Pingchou, now *Shansi* (see 'Taiyuan Fu').
211	573		Liangchou Fu, *Kansu.* Many castles and houses destroyed.
212	587	March.	Earthquake. [Biot says from the year 402 to 587 civil war interfered with keeping of registers.]
213	594	June.	The Imperial City, Changan, Hsian Fu, *Shensi.*
214	600	Dec. 16.	All China was shaken.
215	602	April.	Chiyung (now Fenghsiang Fu), *Shensi.*
216	619	Nov.	Imperial City, Changan, Hsian Fu, *Shensi.*
217	624	July.	Tsunchou (now Changyang), in Wuchang Fu, *Hupeh.* Ground slipped down from mountains and a river overflowed.
218	633	Nov. 30.	Imperial City, Changan, Hsian Fu, *Shensi.*
219	638	Feb. 15.	Sung and Tsung, Lungan Fu, *Ssuchuan.* Many houses destroyed. (One book gives the date as the 22nd.)
220	646	Nov. 8.	Lingchou, Ninghsia, *Kansu.* It made a noise like thunder. (One book gives the date as the 15th.)
221	649	Sept. 15.	Hotung, comprising Puchou Fu, Pingling, Chiang-Ho, Chieh, *Shansi.* Most damage occurred at Puchou; more than fifty people killed. (One book gives the date as Aug. 1st.)
222	649	Sept. 17.	Earthquake, ditto. (One book gives the date as the 3rd.)
223	650	Jan. 5.	Ditto.
224	650	May 9.	Ditto.
225	650	May 19.	Ditto.
226	650	July 19.	Earthquake. Made a noise like thunder.
227	651	Nov.	Ditto.
228	652	Jan. 8.	Tinghsiang, Hsin, *Shansi.*
229	677	Feb. 29.	Imperial City, Changan, Hsian, *Shensi* (B, April 25).
230	680	Nov. 9.	Earthquake, ditto.
231	682	Nov. 13.	Ditto.
232	686	Sept.	Hsingfeng, Kanchou Fu, *Kansu* (B, earthquake ?). Mountain displaced and water rose to a height of 20 feet.
233	687	Aug. 29.	Imperial City, Changan, Hsian, *Shensi* (B, Oct. 25).
234	688	Aug. 6.	Ditto.
235	688	Sept. 16.	Shentu.
236	694	May 7.	Changchou Fu, *Kiangsu.*
237	705	July 2.	Yangchou Fu, Changchou Fu, Jun (now Chenchiang), and Suchou Fu in *Kiangsu.* These places are at opposite sides of the river Yangtsze.
238	706		Chiennan and six other districts, *Ssuchuan.* Chiennan is now called Chentu.
239	710	July 2.	Yengchou Fu, *Kiangsu* (B, June 28).
240	712	Feb. 18.	Pingyang Fu, Fenchou Fu, Chiang, in *Shansi.* Many houses destroyed, and more than a hundred people killed.
241	729	May 21.	Earthquake and thunderstorm at Lantien, Hsian, *Shensi.* A mountain was displaced.
212	734	Mar. 24.	Chinchou (now Kungchang), *Kansu.* The shock was followed by many loud noises; many houses were destroyed, and about four thousand people were killed.
243	738	April 23.	Imperial City, Changan, Hsian Fu, *Shensi.*
244	756	Dec. 1.	Hohsi (north-west of Ninghsia Fu, *Kansu*), Changyeh, in Kanchou, and Chiuchuan (now Suchou Fu), *Kansu.* It was followed by a loud noise. The greatest damage occurred at Changyeh and Chiuchuan, where many houses were destroyed, and many people lost their lives. The ground did not come to rest until March, 757

No.	Date. A.D.		
245	767	Dec. 25.	Imperial City, Changan, Hsian Fu, *Shensi.* Motion was from N.E., and a loud noise was repeated three times.
246	768	May.	Imperial City, Changan, Hsian Fu, *Shensi* (B, July 2).
247	777		In the Tingho Circuit, *Chihli.* The greatest damage was at Tzulu, in Paoting Fu, and Ningchin. The land was fissured, and sand and water were ejected. Many houses were destroyed and many people were killed. The ground did not come to rest for many days.
248	780	May 17.	Imperial City, Changan, Hsian, *Shensi.*
249	782	July 31.	Ditto.
250	783	May 27.	Ditto.
251	783	July 3.	Ditto. (B, June.)
252	786	June 25.	Ditto.
253	788	Jan. 13.	Tungtu (now Honan Fu), Shan, in *Honan*, and Pu, in Hsi, *Shansi.*
254	788	Feb. 16.	Imperial City.
255	788	Feb. 17.	The whole of China was shaken, but the most damage was done at Kin, in *Hunan*, and Fang, in Yunyang Fu, *Hupeh.* A mountain was displaced, the ground opened, and water gushed forth, many houses were destroyed, and people lived in the open air until movement had ceased.
256	—	Feb. 18.	
257	788	Mar. 4.	
258	788	Mar. 7.	
259	788	Mar. 11.	
260	788	Mar. 14.	
261	788	Mar. 15.	
262	788	Mar. 16.	
263	788	Mar. 18.	Imperial City. (B, Feb. 13, 14, 29; also March 1, 3, 6, 7, and 8.)
264	788	Mar. 20.	The whole of China. The Imperial City was destroyed. (B, March 17, 18, 29; April 16, 21; May 2, 3; also June 27 and 28.)
265	788	Mar. 21.	
266	788	April 1.	
267	788	April 20.	
268	788	April 25	
269	788	May 6.	
270	788	May 7.	
271	788	July 1.	
272	788	July 2.	
273	788	Sept. 27.	The Imperial City. The shocks were followed by noise like thunder.
274	788	Oct. 3.	Imperial City.
275	792		Earthquake.
276	793	May 31.	Imperial City and neighbouring districts. Most damage was done at Hochung Fu (Puchou Fu), *Shansi*, and Kuannei, *Shensi.* Many of the castle walls and houses were destroyed. The ground opened and water burst forth.
277	794	May 13.	Imperial City.
278	794	May 18.	Ditto.
279	797	Aug. 12.	Ditto.
280	812	Sept.	Imperial City. Many trees fell down.
281	814	April 5.	Suichou, Lichiang Fu, *Yunnan.* During a day and night there were more than eighty shocks. There was a landslip thirty Chinese miles (about ten miles) in length, and more than a hundred people were killed.
282	815	Nov.	Imperial City, Changan, Hsian, *Shensi.*
283	816	Mar. 23.	Imperial City (B, April 12).
284	820	Jan.	Imperial City, Changan (B, March 13).
285	828	Feb. 7	Imperial City, Changan.
286	833	July 12.	Imperial City, Changan (B, August 4).
287	835	April 15.	Imperial City, Changan. Many tiles shaken down from roofs.
288	836	Feb. 28.	Imperial City.
289	837	Feb. 10.	Imperial City (also a slight shock in old Tungshu).
290	839	Dec.	Imperial City.
291	842	Mar. 17.	Sung and Po, now forming Honan Fu, *Honan* (B, 843, March 8.)
292	843	Feb. 13.	Imperial City, Changan, Hsian Fu, *Shensi.*
293	844	Jan. 16	Earthquake.

No.	Date. A.D.		
294	849	Oct. 24.	Shangtu (also called Luanching), *Chihli*, also Chenwu, Kueihuacheng, Soping Fu, *Shansi*, Hosi (now Chaoyi), in Hsian Fu, Tiente, Lingwu in Hsienyang and Yenhsia, *Shensi*. Many houses destroyed and many people killed (B, 848, Oct. 25).
295	858	Oct. 13.	Taiyuan in Chinning, *Shansi*.
296	860	May	Shangtu, *Chihli*.
297	865	Dec.	Chin, Chiang in Hotung (Taiyuan Fu), *Shansi*. Many houses destroyed; the ground was cracked and water came forth.
298	867	Feb. 23.	Hochung, Puchou Fu, Chin and Chiang, Taiyuan Fu, in *Shansi*. Many houses destroyed and many people killed.
299	872	May 15.	Chetung and Chesi, Hangchou Fu, *Chehkiang*.
300	876	July 18.	Hsiungchou in Paoting Fu, *Chihli*. The town was destroyed; a landslip took place, many people were killed, and shocks continued for four months.
301	876	July	Puchou, Tsaechou Fu, *Shangtung*.
302	876	Dec.	Imperial City, Changan, Hsian Fu, *Shensi*. Shocks were accompanied by sounds.
303	877	Aug. 7.	Hsingchou in Paoting Fu, *Chihli*.
304	879	March.	Imperial City. Followed by a loud noise like thunder. A mountain was displaced and water burst out at Lantien in Hsian Fu, *Shensi*.
305	883		Chinchou, Taiyuan Fu, *Shansi*. It was followed by a noise like thunder.
306	886	Spring.	Chengtu in *Ssuchuan*. Many shocks during a single month.
307	887	Jan.	Weichou, comprising the lower part of *Shansi* (Puchou Fu) and part of *Honan*.
308	895	April 11.	Hotung, now *Shansi* (Puchou Fu, Pingyang Fu).
309	924	Dec.	Chenchou, *Kuangtung*.
310	925	Dec. 18.	Wei (now Changyin), Honan Fu, *Honan*; Po in Tungchang, *Shangtung*; Hsuchou Fu, *Kiangsu*; Su in Fengyang Fu, *Anhui*.
311	928	July	Cheng in Kaifeng Fu, *Honan*.
312	932	July	Taiyuan in *Shansi*. The ground did not come to rest until the 27th, and there were twenty shocks.
313	932	Sept.	Chin (now Kungchang), *Kansu*.
314	932	Dec.	Imperial City, Kaifeng, *Honan*.
315	949	May 9.	Yuting (now Yungping Fu), Tsuang in Tientsin Fu, Shen in Chinho, and Pei in Kuangping Fu, *Chihli*. Most damage was done at Yuting.
316	953	Nov.	Wei (now Changyin), Shangte Fu, Lo (Honan Fu), *Honan*, and Hsing (now Shunte Fu), *Chihli*. Most damage at Weichou. There were about fifteen shocks, and the ground did not come to rest for several days.
317	965		Imperial City, Kaifeng Fu, *Honan*.
318	996	Oct.	Tung (now Tzutung), Paoning Fu, *Ssuchuan*; Kuansi forming *Shensi* (Hsian); Ling in Ninghsia Fu, *Kansu*; Hsia (Puchou), forming *Lower Shansi* (Pingyang Fu), Huan and Ching in Chingyang Fu, *Kansu*. Many castle walls and houses were destroyed.
319	999	Oct.	Changchou Fu, containing the cities of Wuchin and Yanghu in *Kiangsu*. Many military stations and houses were destroyed.
320	1001	Sept.	Chingchou (now Chingyung), *Kansu*.
321	1003	Feb.	Yichou, comprising parts of *Yunnan* and *Ssuchuan* (Chengtu Fu).
322	1004	Feb. 10.	Imperial City, Kaifeng, *Honan*.
323	1004	Feb. 17.	Ditto.
324	1004	Feb. 21.	Imperial City, Kaifeng, *Honan*. Many houses badly shaken, and there was a great noise.
325	1004	Feb. 27.	Chichou, comprising *Chihli* (Chengting), *Shansi*, and part of *Honan* and *Manchuria*.

No.	Date. A.D.		
326	1004	March.	Yichou, comprising parts of *Yunnan* and *Ssuchuan* (Chengtu), Lichou in Linan Fu, *Yunnan*, and Yachou in *Ssuchuan*.
327	1004	April.	Chingchou Fu, *Hupeh*.
328	1004	May 23.	Yingchou (now Hochien Fu), *Chihli*.
329	1004	June.	Chingchou Fu, *Hupeh*. Shocks were repeated several times.
330	1004	Dec 22.	Jihnan (now called Yuenan), *Tongking*. The shock extended to the Imperial City, Kaifeng, *Honan*.
331	1004	Dec. 23.	Shihchou, Wenchou Fu, *Chehkiang*.
332	1007	Sept. 12.	Yichou, comprising parts of *Yunnan* and *Ssuchuan* (Chengtu).
333	1007	Sept. 15.	Weichou (now called Kungchang) and Wating, Pingliang Fu, *Kansu*. During the day there were four shocks.
334	1009	April.	Taichou, north part of *Shansi*.
335	1011	July.	Changchou and Meichou, Ningyuan Fu, *Ssuchuan*.
336	1011	August.	Chengching (now called Chingting) in Chingho, *Chihli*. Overturned walls.
337	1022	March.	Liao, Ying, in Tatung Fu, and Yuan, in Chiang, *Shansi*. Many houses were destroyed.
338	1027	May 12.	Taichou in Yangchou Fu, *Kiangsu*, and Hsin, *Shansi*.
339	1029	Dec. 5.	Imperial City, Kaifeng Fu, *Honan* (B, Nov. 29).
340	1037	Dec.	Taichou, Pingchou (Taiyuan Fu), and Hsinchou. These places are in the north part of *Shansi*. The greatest damage was done at Hsinchou, where 19,742 people were killed, 5,655 were wounded, and more than 50,000 cattle were killed. At Taichou 759 people were killed, and at Pingchou 1,890 people killed (B, Jan. 24, 1038).
341	1038	Jan.	Imperial City, Kaifeng, *Honan*. (One book gives date as Dec. 1037.)
342	1038	Mar. 7.	Tai, Ping and Hsinchou, *Shansi*. This is where the earthquake took place in December 1037.
343	1038	Dec.	Hsinchou, *Shansi*.
344	1039	Jan. 5.	Imperial City, Kaifeng Fu, *Honan*.
345	1043	June 19.	Hsinchou, *Shansi*. Followed by a loud noise.
346	1043	June 24.	Hsinchou, *Shansi*.
347	1045	Sept. 3.	Kuangchou or Cantong Fu, *Kuangtung*.
348	1045	Sept. 9.	Kingnan and Yochou, *Hunan*.
349	1046	Feb. 12.	Chingchou Fu, *Shantung* (B, April 6).
350	1046	April 24.	Tengchou Fu, *Shantung*. A mountain was displaced and there was a noise in the sea.
351	1046	June 17.	Imperial City, Kaifeng Fu, *Honan*.
352	1047	Nov. 20.	Ayang and Hsuchou, *Honan*.
353	1050	Dec. 6.	Hsiuchou, Chian, *Kiangsi*. A loud noise like thunder came from the north-west.
354	1056	Jan. 4.	Chiahsing Fu, *Chehkiang*.
355	1057		Hsiungchou in Paoting Fu and Pachou in Shuntien Fu, *Chihli*. The greatest damage was at Yuchou in the northern part of Hsiungchou. More than twenty or thirty thousand people were killed.
356	1060	June 8.	Imperial City, Kaifeng Fu, *Honan*.
357	1067		Chuanchou, Changchou, Chienchou, Shaowu, Hsinghuachun, in *Fuhkien*, and Chaochou Fu, in *Kuangtung*. Most damage was done at Chaochou Fu: the ground opened, water burst forth, and many people were killed.
358	1067	Oct. 10.	Imperial City, Kaifeng Fu, *Honan*.
359	1068	Aug. 20.	Ditto.
360	1068	Aug. 21.	Ditto.
361	1068	Aug. 27.	Ditto.
362	1068		Hui and Tunga in Yunchou (now called Tungping), Taian Fu, *Shantung*. Shocks were repeated all day; a violent earthquake occurred at Tsangchou, Chingchih and Mochou, Hochian Fu, *Chihli*, and Hopei in *Honan*, comprising Chante Fu, Weihui Fu, and Huaiching Fu. Many castle walls and houses were destroyed and many people killed.

No.	Date. A.D.		
363	1068		Yiyang in the Chansha Fu, *Hunan*. A mountain was displaced with a loud noise.
364	1068	Sept. 3.	Mochou, Hochien Fu, *Chihli*. Accompanied with loud noise.
365	1068	Dec. 29.	Imperial City, Kaifeng, *Honan*; also at Mochou, *Chihli*.
366	1069	Jan. 6.	Yingchou, Hsuchou Fu, *Ssuchuan*.
367	1069	Jan. 20.	Chichou in Chingho, Paoting Fu, *Chihli*.
368	1069	Jan. 24.	Tsungchou in Tientsin Fu, *Chihli*. Muddy water burst out from the ground, bringing with it wood, nuts, shells, &c.
369	1069	Jan.	Chaochou Fu, *Kuangtung*. Shocks were repeated more than ten times in the day, and the ground did not come to rest for more than six months.
370	1072	Nov. 3.	Hua, Tungchou Fu, *Shensi*.
371	1085	June 14.	Imperial City, Kaifeng, *Honan*.
372	1087	April 10.	Taichou, northern part of *Shansi*. The shock was followed by a loud noise.
373	1089	Spring.	Shensi, comprising part of *Shensi* and *Kansu* (*see* Hsian Fu); also Hopei, Huaching Fu, in *Honan*.
374	1092	Nov. 7.	Lanchou, Cheniung, Pingliang Fu, in *Kansu*; also Yunghsing (now called Hsian Fu), *Shensi*.
375	1092	Nov. 8.	Huanchou, Chingyang Fu, *Kansu*.
376	1095	Jan. 13.	Taiyuan Fu in *Shansi*.
377	1095	Nov.	Honan Fu, *Honan*.
378	1095		Suchou Fu, *Kiangsu*. Shocks were repeated many times from summer to autumn.
379	1096	April 9.	Chiennan and Tungchuan (now called Chengtu Fu, *Ssuchuan*).
380	1096	Oct. 17.	Chuchou, *Anhui*, and Yichou, *Shantung*.
381	1097	Aug. 4.	Taiyuan Fu, *Shansi*. It was followed by a loud noise
382	1098	Aug. 31.	There was an earthquake which lasted a long time.
383	1099	Feb. 27.	Enchou in Tungchang Fu, *Shantung*.
384	1099	Aug. 28.	Taiyuan Fu, *Shansi*.
385	1100	June 19.	Ditto.
386	1102	Jan. 23.	Chin, Hsi, Tai, Lan, Kelan, Paote, Ningwu, in Taiyuan Fu, *Shansi*; Shih (now Wupao) and Weisheng, Suite Fu, *Shensi*. These places are on opposite sides of the valley, through which the Yellow River runs in a north-south direction. Shocks were repeated day and night, and many castle walls and houses were destroyed and many people were killed.
387	1122		Hsingchou in Paoting, *Chihli*.
388	1124	Feb.	Imperial City, Kaifeng, *Honan*. The ground did not come to rest for several days. Shocks were followed by a loud noise.
389	1125	Sept. 6.	In the Hsiho Circuit, in the northern part of *Kansu*. Most damage done was at Lunchou. The ground sank to a depth of 40 or 60 feet, and several hundred houses and people were buried.
390	1128	Feb. 22.	Changan, the prefectural city of Hsian Fu, *Shensi*.
391	1133	Sept. 9.	Pingchiang, Yochou Fu, *Hunan*. Most damage was done at Huchou (B, Oct. 12).
392	1134		Hsingtu, in Chenting Fu, *Chihli*.
393	1135	June.	Chengtu Fu, *Ssuchuan*.
394	1136	July 16.	Yuhang, Hangchou Fu, *Chehkiang*. Shock was followed by loud noise like thunder.
395	1137		Earthquake.
396	1137	Aug. 21.	Imperial City, Kaifeng, *Honan*.
397	1141	Jan. 23.	Ditto.
398	1144	Nov. 30.	Ditto.
399	1154	Mar. 17.	Earthquake.
400	1155	May 5.	Earthquake (B, April 28).
401	1158	Sept. 28.	Earthquake.
402	1160	April 7.	Hotung (Puchou and Pingyang), *Shansi*, and Tungchou Fu, *Shensi*.
403	1161	April 23.	Ditto.
404	1162	Sept. 1.	Ditto (B, Aug. 25).

No.	Date. A.D.		
405	1163	July 24.	Earthquake.
406	1163	Nov. 24.	Ditto.
407	1164	March.	Imperial City, Kaifeng, *Honan.*
408	1165	Aug. 14.	Imperial City, Kaifeng, *Honan.* Accompanied by a loud noise.
409	1165	Aug. 16.	Imperial City, Kaifeng, *Honan.*
410	1166	Oct. 9.	Ditto.
411	1167	Nov. 6.	Earthquake.
412	1169	Jan. 31.	Shihchou, Suiting Fu, *Ssuchuan.* The movement continued for three days, and was accompanied by sounds. The tiles fell from many roofs.
413	1175	Jan. 16.	Imperial City, Kaifeng, *Honan.*
414	1180	June 16.	Ditto.
415	1183	Jan. 8.	Earthquake, Kaifeng, *Honan.*
416	1184	Jan. 27.	Ditto.
417	1185	June 14.	Ditto.
418	1187	June 15.	Ditto.
419	1195	April 10.	Earthquake, Kaifeng, *Honan,* accompanied by a thunderstorm. The Palace gate was damaged.
420	1195	Sept.	Imperial City, Kaifeng, *Honan.*
421	1200	July 15.	Ditto.
422	1200	Oct.	Earthquake in North-East China (Shangtu ?).
423	1200	Dec. 19.	Ditto.
424	1200	Dec. 26.	Ditto.
425	1209	Dec. 11.	Pingyang Fu, *Shansi.* The motion was from north-west, and was followed by a loud noise.
426	1209	Dec. 23.	In the same district. The greatest damage was at Fushan in Pingyang Fu. Many castles and houses were destroyed and many people were killed.
427	1210	Mar. 31.	Heavy shock in the same district. Movement did not cease until the end of September. The shocks were accompanied with noise.
428	1213	May.	Hsingtu.
429	1213	July 3.	Yenchou Fu, *Chehkiang* (B, June 26).
430	1216	Mar. 25.	East Hsichuan, Hsining Fu, *Kansu.* The ground did not come to rest for four days.
431	1217	Mar. 28.	Imperial City, Kaifeng Fu, *Honan.*
432	1219	June 9.	Pingliang and Chenjung in Pingliang Fu, *Kansu.* It was accompanied by a loud noise and followed by a dust storm, which made the whole day dark The damage was so great that it was impossible to find out how many houses had been destroyed and how many people had been killed.
433	1219	June.	Imperial City, Kaifeng, *Honan.*
434	1219	July.	Hsichuan, Hsining, *Kansu.*
435	1220	July 30.	Earthquake.
436	1221	Feb. 10.	Earthquake and thunderstorm.
437	1221	June 11.	Hsichuan, Hsining Fu, *Kansu.*
438	1223	Oct. 1.	Earthquake.
439	1241	Jan. 16.	Ditto.
440	1242	Feb. 25.	Ditto.
441	1255		Shu (the literary name of *Ssuchuan*), Chengtu Fu.
442	1270		Chiating Fu (now Sungpan), Lungan Fu, *Ssuchuan.*
443	1274	Oct. 23.	Imperial City, Tatu (now Peking).
444	1284	Oct. 19.	Peking.
445	1289	Feb. 4.	Earthquake, Peking.
446	1290	Mar. 28.	Chuanchou Fu, *Fuhkien.*
447	1290	Mar. 31.	Earthquake, Chuanchou Fu, *Fuhkien.*
448	1290	Sept. 27.	Shangtu (also called Luanking), *Chihli,* and Wuping, Tingchou Fu, *Fuhkien.* At Wuping 100,000 people were killed.
449	1291	Sept.	Pingyang Fu, *Shansi.* Eighteen thousand houses were destroyed.
450	1295	April 11.	Earthquake.

No.	Date. A.D.		
451	1302	Dec. 29.	Yunnan Fu, *Yunnan*. The ground did not come to rest for several days.
452	1302	Dec.	Ditto.
453	1303	Sept.	Pingyang Fu, Taiyuan Fu, *Shansi*. The land opened, and water and sand came out of the fissures; 100,000 houses were destroyed and many people were killed. A landslip, more than ten Chinese miles in length, took place. This was at Chaoching in Pingyang Fu. At Hsukou, Chi, and Pingchou, in Taiyuan Fu, the ground opened and water burst out to form a stream. At Pingchou the north castle wall was destroyed for the length of one Chinese mile; on the east side it was destroyed for a length of 200 feet. At Pingyang Fu the ground did not come to rest until February 1304. (3 Chinese = 1 English mile.)
454	1304	Feb.	Pingyang Fu, *Shansi*. Many houses were destroyed.
455	1305	May.	Tatung Fu, *Shansi*. It was accompanied with a noise like thunder, and 5,800 houses were destroyed and 1,400 people were killed. At Huaijen in Tatung Fu water burst out at two places to form lakes, and was black in colour: one of these lakes had an area of 18 pu (240 pu = 1 acre) and a depth of 115 feet; the other was 66 pu and 10 feet in depth.
456	1305	June 18.	Pingyang Fu and Taiyuan Fu, *Shansi*. In order to stop the continually occurring earthquakes the Government ordered the names Pingyang and Taiyuan to be changed to Chinning and Chining.
457	1305	Dec. 2.	Tatung Fu, *Shansi*.
458	1305	Dec.	Earthquake.
459	1306	Jan.	The shocks still continued at Chinning and Chining. They apparently commenced in 1303.
460	1306	May 12.	Kaicheng, Yenan Fu, *Shensi*.
461	1307	Sept. 15.	Kaicheng, Yenan Fu, *Shensi*.
462	1308	July 6.	Ningyuan district in the Lunghsi of Kungchang, *Kansu*. Also there was a great earthquake in Wumeng in Chaotung Fu, *Yunnan*. There were six heavy shocks in three days.
463	1308	Sept.	Puchou, *Shansi*.
464	1308	Oct. 30.	Puchou, *Shansi*, and Ling, in Ninghsia Fu, *Kansu*.
465	1310	Jan. 22.	Yangchu in Taiyuan Fu, *Shansi*. The shock was followed by a great noise.
466	1311	Jan. 3.	Chining (Pingyang), *Shansi*.
467	1311	April 24.	Ninghsia, *Kansu*.
468	1311	Aug. 6.	Kanchou Fu in Kanliang, *Kansu*. There was a noise like thunder and a hurricane.
469	1311	Sept. 16.	Ninghsia, *Kansu*.
470	1313	July.	Imperial City, Peking, *Chihli* (B, June 24).
471	1313	July 3.	Imperial City, Peking, *Chihli*.
472	1313	July.	Ditto.
473	1313	July 22.	Ditto.
474	1314	Mar. 8.	Taning, Hsi, *Shansi*.
475	1314	May 23.	Taning, Hsi, *Shansi*. Followed by noise.
476	1314	Sept. 14.	Piengliang (now Kaifeng), Chih (now Wuchih), in Huaiching Fu, Wuan, in Chante Fu, *Honan* (B, Oct. 5).
477	1315	Jan. 2.	Taning in Hsi, *Shansi*, accompanied by a noise like thunder.
478	1316	Aug.	Chining and Chinning, *Shansi*. Accompanied by a noise like thunder (B, Oct. 7).
479	1316	Nov. 6.	Honan Fu, *Honan*.
480	1317	Feb. 13.	Chining, *Shansi*. Accompanied by a noise.
481	1317	Sept. 11.	Ditto.
482	1317	Oct. 9.	Lingpei (outside the great wall to the north of *Kansu*). Shocks were repeated for three days.
483	1318	Feb. 21.	Earthquake, Yichou, Liaotung, *Shingking*.
484	1318	Mar. 12.	Honing in Lingpei, *Kansu*.
485	1318	April 27.	Teching in Chaoching Fu, *Kuangtung* (B, June 18).

No.	Date. A.D.		
486	1322	Nov. 17.	Earthquake, Peking.
487	1322	Dec. 25.	Ditto.
488	1324	Jan. 1.	Fengyuan (now Changan) in Hsian Fu, *Shensi*. Accompanied by a noise.
489	1326	Jan. 19.	Ninghsia, *Kansu*. Accompanied by sound. Shocks repeated three times.
490	1327	April 5.	Honing in Lingpei, *Kansu*. Accompanied by loud noise.
491	1327	Aug.	Tungwei in Kungchang Fu, *Kansu*. A mountain was displaced. At Tiaomen the shock made a great noise. On the same day there was also a shock at Fenghsiang Fu and Hsingyuan, Hanchung Fu, *Shensi*; Chentu, *Ssuchuan*; Shenchou and Chiangling in Chingchou, *Hupeh*.
492	1327	Sept. 30.	Ninghsia, *Kansu*.
493	1328	Aug. 14.	Earthquake, *Kansu*.
494	1328	Sept. 1.	Taning, Hsi, *Shansi*.
495	1328	Nov. 24.	Taning, Hsi, *Shansi* (B, 14th)
496	1331	May.	In the Chih district (now Wuchih) in Huaiching Fu, *Honan*, and Chenting Fu, *Chihli*. The ground shook continuously for more than a month.
497	1332	May 4.	Liaotung, or Liaoyang, *Shingking*.
498	1332	June.	Peking.
499	1332	Sept. 2.	Lunghsi, Kungchang, *Kansu*.
500	1332	Oct.	Earthquake.
501	1333	May.	Taning, Hsi, *Shansi*.
502	1333	June.	Imperial City, Peking. Accompanied by sound.
503	1333	Sept.	Lunghsi in Kungchang, *Kansu*.
504	1333	Dec. 28.	Hsunshan district in Anching Fu, *Anhui*.
505	1333	Dec.	Leping and Tehsing districts, in Jaochou Fu, *Kiangsi*.
506	1334	May.	Hsingchou, now forming Chi, Shuntien Fu, *Chihli*.
507	1334	Sept. 22.	Imperial City, Peking. A cock crowed before the earthquake commenced. A mountain disappeared, and where it stood a lake was formed, the area of which was a hundred square miles. Many people were killed.
508	1335	Dec. 17.	Hsingkuo, Wuchang Fu, *Hupeh*.
509	1336	Jan. 21.	Anching, *Anhui*. The most damage was done in Susung, Taihu, Hsunshan districts. At the same time there was an earthquake at Luchou in *Anhui*, Chichou, Huangchou Fu, *Hupeh*.
510	1336		Jaochou, *Kiangsi*.
511	1336	Mar. 9.	Susung, Anching, *Anhui*.
512	1337	Sept. 17.	Imperial City, Peking. Many houses were destroyed, and many people and cattle were killed at Shunchou, near Shunyi, Lungching, Huailai, Hsuante (now Hsuanhua), *Chihli*.
513	1337	Sept. 18.	Imperial City, Peking.
514	1338		Paoan, Hsuanhua Fu, *Chihli*, and Hsinchang in Juichou Fu, *Kiangsi*.
515	1338	July.	Hsinchou, Shuntien Fu, *Chihli*. Mount Ling was displaced.
516	1338	Aug. 10.	Paoanchou, Hsuanhua Fu, *Chihli*.
517	1338	Aug.	A mountain was displaced at Kungchang, *Kansu*.
518	1338	Sept. 6.	Imperial City, Peking. Shocks occurred two or three times during the day.
519	1341	March.	Pingliang (now Kaifeng), *Honan*.
520	1342	June 7.	Pingchin in Chining (now Taiyuan), *Shansi*. Accompanied by a loud noise like thunder. Land opened and many houses were thrown out of the vertical.
521	1343	Jan. 17.	Imperial City, Peking.
522	1343	March.	Chunchou (now Yu), Hsincheng and Mi in Kaifeng Fu, *Honan*.
523	1343	Dec.	Chiaochou, Kaomi, Laichou Fu, *Shantung*.
524	1344	Aug. 9.	Wenchou Fu, *Chehkiang*.
525	1344	Sept.	Chu and Mingyin in Yichou Fu, *Shantung*.

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526	1345	Jan.	Tungping, Tunga in Taian Fu, Yangku in Yenchou Fu, Pingyin, Chinan Fu, *Shantung*, and Hanyang, *Hupeh*.
527	1345	June.	At four districts in Chichou, Shuntien Fu, *Chihli*, and Tungping, Taian Fu, in *Shantung*.
528	1346	Jan.	Chenchiang Fu, *Kiangsu*, and Chinan Fu, *Shantung*.
529	1346	March.	Yitu, Changle, Shoukuang in Chingchou Fu, Peihai in Weichou, and Chiaochou in Laichou Fu, *Shantung*.
530	1346	April.	Kaoyuan in Chingchou Fu, *Shantung*. Many houses were destroyed.
531	1346	Sept.	Shaowu Fu, *Fuhkien*. Next day drum-like sounds were heard in the ground, and also in the following night.
532	1347	March.	Yitu, Lintsu, Linchu in Chingchou Fu, Changyi of Weichou, Kaomi of Chiaochou in Laichou Fu, and Tichou of Chinan Fu, *Shantung*.
533	1347	April.	Tungping, Tunga in Taian Fu, Yanku in Yenchou Fu, Pingyin in Chinan Fu, *Shantung*.
534	1347	June	Lintzu, Chingchou Fu, *Shantung*. The ground did not come to rest for several days; at Hotung (Puchou, Pingyang), *Shansi*, the ground was fissured and water burst forth; many houses were destroyed and many people killed.
535	1347	July 12.	Tanyang, Chenchiang Fu, *Kiangsu*.
536	1349	July	Taichou Fu, *Chehkiang*.
537	1350	Nov.	Hsukao in Taiyuan Fu, *Shansi*.
538	1351	May 22.	Fen, Hsin, Wenshui, Pingchin, Yutzu, and Shouyang, in Taiyuan Fu, Yushe of Liao in Chinning (now Pingyang Fu, *Shansi*), and Honei, Hsiuwu, Menchou, in Huaiching Fu, *Honan*. The shock was followed by a noise like thunder; many houses were destroyed and many people killed and wounded.
539	1351	Sept.	Kungan, Sungtsu, Chehchiang, Chingchou Fu, Hsia (now Yichang Fu), and Chingmen, Chengtien Fu (now Anlu Fu), *Hupeh*.
540	1352		Lingshih in Ho (Pingyang Fu), *Shansi*.
541	1352	April	Shensi (the provinces comprise part of *Kansu*, the north-west part of *Ssuchuan*, and the present *Shensi*). Most damage was done at Chuanglang Tinghsi in Liangchou Fu, Chingning in Pingliang Fu, and Huichou (now Huan) in Chingyang, *Kansu*. Many houses were destroyed; a mountain was moved and a valley filled up.
542	1353		Chuanglang, Liangchou Fu, Tingsi, Kungchang Fu, Chingning, Pingliang Fu, and Huichou, Lanchou Fu, *Kansu*.
543	1354	May	Chiehhsiu, Fenchou Fu, *Shansi*. Water burst out.
544	1354	Aug.	Hsiaoyi, Fenchou Fu, *Shansi*.
545	1354	Dec.	Ningkuo, Chingte in Ningkuo Fu, *Anhui*.
546	1354	Dec.	Haichou in Huaian Fu, *Kiangsu*.
547	1355	Jan.	Shaohsing Fu, *Chehkiang*.
548	1355	Aug. 9.	Paote in Chining (now Taiyuan Fu), *Shansi*.
549	1356	Spring.	Chichou (Shuntien Fu) and four other districts in *Chihli*. The ground did not come to rest for ten days.
555	1356	July	Leichou Fu, *Kuantung*.
550	1358	Mar. 25.	Linchou in Chinning (Taiyuan Fu), *Shansi*.
521	1358	June	Yitu in Chingchou, *Shantung*.
553	1359	Feb.	Chingyuan in Chuchou Fu, *Chehkiang*.
554	1360	April	Shunchang in Yenping Fu in *Fuhkien*.
555	1362	April	Nanhsiung, *Kuangtung*.
556	1363	Feb. 3.	Taichou Fu, *Chehkiang*.
557	1365	Oct.	Hsinghua Fu, *Fuhkien*. With a noise like thunder.
558	1366	April.	Haichou in Huaian Fu, *Kiangsu*. With a noise like thunder.
559	1366	July.	Chiehhsiu in Fenchou Fu, *Shansi*.
560	1366	Aug.	Hsin, Lin, Shih in Hsukao of Taiyuan and Hsiaoyi, Pingyao in Fenchou, *Shansi*. Many people were killed.
561	1366		Kung, Honan Fu, *Honan*. A mountain was displaced.

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562	1367	June.	Chinan, *Shantung*.
563	1367	Nov. 13.	Fuhchou, *Fuhkien*.
564	1368	Jan. 26.	Fuhchou, *Fuhkien*. With a noise like thunder.
565	1368	June.	Wenshui, Hsukao in Taiyuan Fu, Hsiaoyi, Chiehhsiu in Fenchou Fu, Paote of Linchou, Shihlou of Shi, *Shansi* and Shensi (comprising *Shensi* and *Kansu*) (*see* Hsian Fu, *Shensi*).
566	1368	Dec. 2.	Shensi, now represented by *Shensi* and *Kansu* (*see* Hsian).
567	1371		Kungchang, Lintao, and Chingyang, *Kansu*.
568	1372	June 1.	Tsangwu in Wuchou Fu, Hochou, Kungcheng and Lishan (now Yungan in Pingle Fu), *Kuangsi*.
569	1372	Aug. 6, 13.	Yangchu, Taiyuan Fu, *Shansi*.
570	1372	Aug. 24.	The Imperial City, Nanking, *Kiangsu*. Sixteen people were killed.
571	1372	Sept. 14.	Hsukao, Taiyuan Fu, *Shansi*. The ground did not come to rest for three days, and loud noises came from the north-west.
572	1372	Sept. 29.	Yangchu, Taiyuan Fu, *Shansi*.
573	1372	Oct. 23.	Ditto.
574	1372	Nov. 8.	Ditto.
575	1372	Nov. 21.	Ditto.
576	1372		Yangchu, Taiyuan Fu, *Shansi*. The shocks were repeated seven times during the year; the ground did not come to rest for eight years.
577	1375	May.	Imperial City, Nanking (now Chiangning), *Kiangsu*.
578	1376	Jan. 2.	Ditto.
579	1378	May 8.	Ninghsia in north *Kansu*. It destroyed many castle walls.
580	1382	Jan. 22.	Fuhchou Fu, *Fuhkien*, Kuangchou Fu or Canton, *Kuangtung*, and Hochou, Lanchou Fu, *Kansu*.
581	1386	July 21.	Yunnan Fu, *Yunnan*.
582	1390	Dec. 27.	Ditto.
583	1394	Feb. 9.	Chinan, *Shantung*.
584	1399	May 7.	Imperial City, Nanking, *Kiangsu*.
585	1403	Dec. 18.	Peking, Taiyuan Fu, *Shansi*, Ninghsia, in *Kansu*.
586	1404	Dec. 26.	Imperial City, Nanking, Chinan Fu, *Shantung*, and Kaifeng Fu, *Honan*.
587	1408	June 17.	Imperial City, Nanking.
588	1413	Sept. 22.	Ditto.
589	1415	Nov. 8.	Peking.
590	1419	Oct. 14.	Ditto.
591	1420	Aug. 9.	Ditto.
592	1424	Aug. 3.	Nanking.
593	1425	Mar. 16.	Liuan, Luchou Fu, *Anhui*, and Nanking, where the ground did not come to rest for seven days; there were about forty-two shocks.
594	1426	Aug. 14.	Imperial City, Peking. The motion was from south-east to north-west, and there was a loud noise.
595	1427		Nanking. Shocks occurred ten times in a day.
596	1428		Nanking.
597	1429		Peking and Nanking.
598	1430	Feb. 12.	Nanking.
599	1430	Feb 21.	Ditto.
600	1438	April 18.	Imperial City, Peking.
601	1438	April 19.	Ditto.
602	1438	April 23.	Ditto.
603	1439	Aug. 7.	Ditto.
604	1439	Sept. 12.	Ditto.
605	1440	Nov. 4.	Chuanglang in Liangchou Fu, *Kansu*. The ground did not come to rest from October to the end of November; there were about twenty shocks; castle walls and houses were destroyed and many people were killed.
606	1445	Mar. 30.	Imperial City, Peking.
607	1451	Aug. 22.	Ditto.

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608	1452		Nanking.
609	1454	Nov. 21.	Imperial City, Peking. Accompanied by a loud noise; motion north-west to south-east.
610	1457	Nov. 11.	Nanking.
611	1465	Feb.	Hsiangyang Fu, *Hupeh.*
612	1465	May 12.	Tiaochou, Tientsin Fu, *Chihli.* The ground did not come to rest for twenty-two days.
613	1465	May 12.	A strong earthquake also occurred in Chengtu Fu, *Ssuchuan*, and shocks were repeated 375 times.
614	1467		Earthquake.
615	1467	June 28.	Hsuanhua Fu, *Chihli*, and Tatung Fu, *Shansi.* There was also a strong earthquake at Sochou in Soping Fu and Weiyuen, *Shansi*; many people were wounded.
616	1468	Sept. 1.	Imperial City, Peking. Accompanied with sound.
617	1469	Jan. 3.	In Hukuang. This province comprises Changsha Fu, *Hunan*, and Wuchang Fu, *Hupeh.*
618	1470	Jan. 18.	Juning Fu. *Honan*, Wuchung Fu, Hanyang Fu, *Hupeh*, and Yochou Fu in *Hunan.*
619	1470	Feb. 18.	*Honan* and Hukuang comprising *Hunan* and *Hupeh* (Wuchang).
620	1470		Hukuang, Wuchang, *Hupeh.*
621	1474	May 23.	Hoching in Lichiang Fu, *Yunnan.* Shocks were repeated fifteen times; many houses were destroyed and many people killed.
622	1474	Dec. 3.	Tashaching in Lingchou, Chingyang Fu, *Kansu.* It made a noise like thunder: shocks were repeated day and night, and many houses were destroyed.
623	1476	Feb. 10.	Nanking, *Kiangsu.*
624	1476	Nov. 6.	Imperial City, Peking.
625	1477	Feb. 22.	Fenyang and Linhuai, *Anhui.* Accompanied by sound.
626	1477	Mar. 28.	Lintao and Kungchang in *Kansu.* It destroyed many castle walls.
627	1477	May 22.	Kanchou, Ninghsia, Liangchou, *Kansu*, Yulin, *Shensi*, and Yichou in *Shangtung.* The greatest damage was done at Ninghsia and Kanchou, where the ground was cracked and the castle walls were damaged in eighty places.
628	1477	Oct. 25.	Imperial City, Peking. Shocks were repeated three times during the day.
629	1478	July	Taiping Fu, *Kuangsi.* Shocks were repeated seven times during the day, and the ground was moving until the end of August.
630	1478	Aug.	Chengtu, *Ssuchuan.* Many houses destroyed and many people were killed.
631	1480	June	Changle, Fuchou Fu, *Fuhkien.*
632	1480	Sept. 23.	Yuehsui in Ningyuan Fu, *Ssuchuan.* Shocks were repeated seven times during the day, and it was several days before the ground came to rest.
633	1481	Mar. 19.	Nanking, Huaian Fu, Yangchou Fu, *Kiangsu*, Fengyang Fu, Luchou Fu, Hochiu, Yingchou Fu, *Anhui*, Yenchou Fu, *Shantung*, and Honan Fu in *Honan.*
634	1481	June 30.	Tsunhua and Suchou, Shuntian Fu, *Chihli.*
635	1481	July 6.	Another earthquake at the same places, and Yungping Fu, *Chihli*, Liaotung, and *Shingking.* Shocks repeated three times during the day.
636	1484	Feb. 7.	Imperial City, Peking, Yungping, Hsuenhua, *Chihli*, and Liaotung. Most damage was done at Hsuenhua; many castles destroyed and many people killed.
637	1484	June 4.	Taichou, *Shansi.* Shocks were repeated seven times.
638	1485	Mar. 15.	Taian Fu, *Shantung.*
639	1485	Mar. 26.	Ditto. Four days later the shock was repeated.
640	1485	April 5.	Earthquake.
641	1485	April 8.	Ditto.
642	1485	April 13.	Ditto.

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643	1485	May 25.	Kuyuan in Pingliang Fu; Lanho, Tao, and Min, in Kungchang Fu, *Kansu*. The shock was followed by a loud noise.
644	1485	June 4.	Chichou, Shuntien Fu, Tsunhua, in *Chihli*. The shock was followed by a loud noise, and the ground did not come to rest for several days. Many castle walls and houses were destroyed.
645	1485	July 4.	Imperial City, Peking.
646	1485	Oct. 25.	Lienchou, *Kuangtung*; and Wuchou, *Kuangsi*. Shocks were repeated many times, and the ground did not come to rest for sixteen days.
647	1485	Dec. 3.	Imperial City, Peking.
648	1486	July 29.	Ningchiang, in Hanchung Fu, and Paochi, in Fengsiang Fu, *Shensi*. At Ningchiang the ground was cracked for a length of 60 to 100 feet. At Paochi there was a crack three Chinese miles in length and 10 feet wide.
649	1486	Oct. 15.	Chengtu Fu, *Ssuchuan*. Shocks were repeated seven or eight times during the day and continued until the day following: they made a noise like thunder.
650	1488	Sept. 25.	Han, Mou, Chengtu Fu, *Ssuchuan*. Thirty-seven houses were damaged and many people were killed.
651	1488	Oct. 1.	A landslip took place at Hsuanhua Fu, *Chihli*: it was 150 yards long, 10 feet wide, and 3 feet in depth. A narrow footpath was elevated in the middle of the river Sha. It was one foot above the surface of the water and 70 yards in length.
652	148	Jan. 12.	Chengtu Fu in *Ssuchuan*. Shocks were repeated many times for three days.
653	1489	June 10.	Chengtu Fu, *Ssuchuan*. Shocks were repeated for three days and noises were heard.
654	1491	Jan. 30.	Imperial City, Peking.
655	1491	July 21.	Ditto.
656	1491	Sept. 23.	Nanking, Huaian, and Yangchou Fu, *Kiangsu*.
657	1493	March.	Ninghsia, *Kansu*. Shocks were repeated twenty times in three years.
658	1493	May 4.	Kaifeng Fu, Weihui, *Honan*, Tungchang Fu, *Shantung*.
659	1494	April 3.	Chuching Fu, *Yunnan*. Many houses destroyed and many people killed. Also at Peking and Nanking. The shocks were repeated six times during the year.
660	1495	April 20.	Ninghsia, *Kansu*. Shocks occurred twelve times, and were followed by loud noise. Walls and houses were damaged, and many people were wounded.
661	1495	Oct. 11-18.	Annan, Hsingyi Fu, *Kueichou*. There were twelve shocks.
662	1495	Nov. 8.	Haichou, *Kiangsu*.
663	1495	Nov. 10.	Ditto.
664	1495		Nanking.
665	1496		Peking and Nanking.
666	1497	Feb. 27.	Imperial City, Peking, and Taiyuan Fu, *Shansi*.
667	1497	July 13.	Haifeng in Wuting Fu, *Shantung*. Shocks were followed by a loud noise and continued for several days.
668	1497		Chenting Fu (now forming Chengting) in Chinho, *Chihli*; Taiyuan Fu, Tunlin, in Luan Fu, *Shansi*; Yulin Fu, *Shensi*; Chenfan in Liangchou Fu, Lingchou, Ninghsia Fu, *Kansu*. The greatest damage was at Tunlin, where tiles fell from the roofs.
669	1500	Aug. 21.	Imperial City, Peking.
670	1500	Nov. 28.	Peking, Nanking, and Fengyang, *Anhui*.
671	1501	Jan. 29.	Yenan, Tung, Hua, Hsingyang, Chaoyi, Changan, in Hsian Fu, Tungkuang, in Tungchou Fu, Hsientung, Finghsiang Fu, *Shensi*; Chingyang, *Kansu*. The greatest damage was done at Chaoyi and Hsiengtung, where castle walls and houses were destroyed and people were killed. Fissures were formed, from which water flowed to form a small

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			river. Movement continued for several months. Each shock was followed by a loud noise. A strong earthquake also occurred at Yungning, Lushi, in Shan Fu, *Honan*; Pingyang and Anyi, Jungho, in Puchou Fu, and Puchou, *Shansi*.
672	1501	Feb. 26.	Puchou Fu, Hsinghua Fu, Chuanchou Fu, and Changchou Fu, *Fuhkien*.
673	1501	Mar. 14.	Puchou, *Shansi*. Shocks were repeated twenty-nine times and the ground did not come to rest until the middle of next month.
674	1501	Oct. 20.	In the province of *Kueichou*. Shocks were repeated three times.
675	1501	Dec. 6.	Nanking.
676	1502	Oct. 27.	Nanking, Hsuchou Fu, *Kiangsu*; Taming Fu, Shunte Fu, *Chihli*; Chinan, Tunchang, Yenchou, and Puchou in Tsaochou Fu, *Shantung*. The greatest damage was at Puchou, where the ground was cracked and water burst forth. More than one hundred people were killed.
677	1502	Oct. 27.	Kaifeng Fu, Changte Fu, *Honan*; Pingyang Fu, Tsechou Fu, and Luan Fu, *Shansi*.
678	1502	Dec. 4.	So, Tai, Ying, Shanyin, Yangchu, and Mayi, Tatung Fu, *Shansi*. The earthquake made a loud noise.
679	1502	Dec. 7.	Nanking.
680	1503	Mar. 31.	Ditto.
681	1505	July 21.	Ninghsia, *Kansu*. The shock was followed by a loud noise; many castles and houses were thrown out of the vertical.
682	1505	Oct. 19.	Hangchou Fu, Chiahsing Fu, Shaohsing Fu, and Ningpo Fu, *Chehkiang*. The shock was followed by a loud noise.
683	1505	Oct. 20.	Nanking, Suchou Fu, Sunchiang Fu, Changchou Fu, Chenchiang Fu, Huaian Fu, Yangchou Fu, and Tung, *Kiangsu*; Ningkuo Fu and Hochou, Taiping Fu, *Anhui*.
684	1505	Oct. 27.	Puchou, Chieh, Chiang, *Shansi*; Hsuanhua Fu, *Chihli*. Greatest damage occurred at Anyi in Chieh and Wanchuan in Hsuanhua Fu, *Chihli*; many houses destroyed and many people killed.
685	1506	Mar. 27 to 29	Hoyang in Tungchou Fu, *Shensi*. Shocks were repeated more than ten times, and each was followed by a loud noise like thunder.
686	1506	May 6.	Yunnan Fu, *Yunnan*. The ground did not come to rest for three or four days; many houses were destroyed and many people were killed.
687	1506	Sept. 7.	Aoshanwei, Laichou Fu, *Shantung*. Many castle walls were damaged; there were many shocks, and each was followed by a loud noise; the ground did not come to rest until December. Altogether there were about forty-five shocks.
688	1507	Nov. 14.	Anchou, Hsinhsingchou, Yunnan Fu, *Yunnan*. Many people were killed. The ground did not come to rest for three days.
689	1509	June 5.	Wuchang Fu, *Hupeh*. The shock was followed by a loud noise and lightning.
690	1509	June 5.	Chuhsiung Fu, *Yunnan*. The ground did not come to rest for three days; there were about five shocks.
691	1510	May.	Chuhsiung Fu, *Yunnan*. Movement continued for thirteen days.
692	1511	Nov. 27.	Tengchuan, Tali Fu, Chienchuan, and Hoching, Lichiang Fu, *Yunnan*. The greatest damage was done at Chienchuan and Hoching, where many people were killed and many houses destroyed.
693	1511	Dec. 12.	Imperial City, Peking, Paoting Fu, Hochien Fu, and eight districts and three towns in *Chihli*, and Wuting Fu in *Shantung*. In three days there were nineteen shocks.
694	1512	June 3.	Chuhsiung Fu, *Yunnan*. There were many shocks, each of which was followed by a noise like thunder.

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695	1512	Oct. 17.	Tengchung (now Tengyuen) in Yungchang Fu, *Yunnan*. Movement continued for three days; red water came out from the ground; many castle walls and houses were destroyed and many people were killed.
696	1514	Jan. 9.	Chengtu Fu, Chungching Fu, Tungchuan Fu, *Ssuchuan*.
697	1514	July 15.	Fengyang Fu, *Anhui*. Followed by a loud noise.
698	1514	Sept. 13.	Peking.
699	1514	Oct. 3.	Hsuchou Fu, *Ssuchuan*, Taiyuan Fu, and Tatung Fu, *Shansi*. Shock followed by a loud noise.
700	1515	June 27.	Yunnan Fu, Chaochou in Tali Fu and Yungning (now Nanning), Chuching Fu, *Yunnan*. For more than a month twenty or thirty shocks occurred each day; the ground was cracked and water burst out; the damage was so great that it was impossible to find out how many houses had been destroyed or how many people had been killed.
701	1515	Oct. 10.	Tali Fu, *Yunnan*.
702	1515	Oct. 29.	Ditto.
703	1516	Sept. 25.	Nanking (forming the present *Anhui* and *Kiangsu*) and Wuchang Fu in *Hupeh*.
704	1517	Jan. 15.	Chuhsiung Fu, Tali Fu, Menghua, and Chingtung, *Yunnan*.
705	1517	May 19.	Yukan, Fengcheng in Fuchou Fu, and Chuanhsi Fu, *Kiansi*; Chinhsiang, Chinning Fu, *Shantung*; Hangchou Fu, *Chehkiang*. The ground did not come to rest until the end of August, and there were about fifteen shocks.
706	1517	July 22.	Hosi, Hsio, Tunghai, in Linan Fu and Hsinhsing, Chengchiang Fu, *Yunnan*. Many houses and castles were destroyed, and many people were killed.
707	1517	Oct. 21.	Chinan, Chingchou, Laichou, and Tengchou Fu, *Shantung*.
708	1517		At Chuanchou Fu, *Fuhkien*. The ground did not come to rest from February to June; at Chinhua, *Chehkiang*, the movement lasted from February to July.
709	1518	July 18.	Chao, Tengchou, Langchiung, in Tali Fu, and Menghua, *Yunnan*.
710	1518	Dec. 10.	
711	1518	Dec. 19.	
712	1519	Mar. 23.	Imperial City, Peking.
713	1519	Oct. 18.	Hsuanhua Fu, Changping, in Shuntien Fu, and Kaiping, *Chihli*.
714	1519	Oct. 28.	Fuchou Fu, Hsingchou Fu, Chuanchou Fu, *Fuhkien*.
715	1520	April 5.	Anning, Yunnan Fu, Hoching, Lichiang Fu, Yao in Chuhsiung Fu, Pinchuan in Tali Fu, and Menghua, *Yunnan*. The greatest damage occurred at Menghua. Many castles and houses were destroyed and many people were killed.
716	1520	Aug. 28.	Chingtung Fu, *Yunnan*. The whole district was damaged and the shocks were followed by a loud noise.
717	1520	Sept. 1.	Chinan, Tungchang, *Shantung*, and Kaifeng, *Honan*.
718	1523	Jan.	Nanking (comprising the present *Anhui* and *Kiangsu*), *Shantung*; *Honan*, and Hsian Fu, *Shensi*.
719	1523	Aug. 24.	Tinghai and many neighbouring districts in *Chehkiang*. Many buildings were destroyed.
720	1524	Feb. 12.	Peking, Nanking; Honan Fu, *Honan*; Chinan, *Shantung*; Taiyuan, *Shansi*; and Hsian, *Shensi*.
721	1524	Feb. 27.	Suchou Fu, Changchou Fu, *Kiangsu*, and Nanking.
722	1525	Sept. 13.	Hsuchou Fu, *Kiangsu*; Fenyang, *Anhui*; Huaiching and Kaifeng, *Honan*. The shock was followed by a loud noise.
723	1525	Oct. 12.	Ditto.
724	1526	May 31.	Yungchang Fu, Tengchung Fu (now Tengyueh), *Yunnan*, and Annan, *Kueichou*. Accompanied by sound.
725	1526	June 9.	Ditto.
726	1527	Nov. 27.	Imperial City, Peking.
727	1533	Sept. 25.	Ditto.
728	1536	Nov. 1.	Imperial City, Peking, and many neighbouring districts. Followed by a loud noise.
729	1537	Oct.	Yunnan Fu, *Yunnan*.
30	1539	Aug. 19.	Linan Fu and Chuhsiung Fu, *Yunnan*, and Pingle Fu, *Kuangsi*.

No.	Date. A.D.		
731	1540	May 25.	Taochou, Kungchang, and Kansu (present Kanchou), *Kansu.*
732	1542	Nov. 14.	Pingyang, *Shansi*; Kuyuan, Pingling Fu, Ninghsia Fu, an Taochou, *Kansu.* Followed by a loud noise.
733	1542	Dec. 26.	Kungchang Fu, Kuyuan, Pingling Fu, *Kansu*; Hsian Fu and Fenghsiang Fu, *Shensi.*
734	1543	April 14.	Taiyuan Fu, *Shansi.* The ground did not come to rest for ten days, and shocks were followed by a loud noise.
735	1543	May 19.	Fuchou, Changchou, Chuanchou, and Hsinghua Fu, *Fuhkien.*
736	1544	April 3.	Taiyuan, *Shansi.* The ground did not come to rest for ten days; the shocks were followed by a loud noise.
737	1548	Aug. 18.	Imperial City, Peking, Shuntien Fu, and Paoting Fu, *Chihli.*
738	1548	Sept. 22.	Imperial City, Peking, Tengchou Fu, *Shantung*; Kuangning in Chaoching Fu, *Kuangtung.*
739	1551	Oct. 10.	Imperial City, Peking. Shocks followed by a loud noise.
740	1552	Mar. 16.	Fengyang Fu, *Anhui.* Shock followed by a loud noise.
741	1552	March.	Taiyuan Fu, *Shansi.* Shock followed by a loud noise.
742	1555	Feb. 3.	*Shansi*, *Shensi*, and *Honan.* Followed by a noise like thunder. The greatest damage was done at Weinan, Chaoyi, Sanyuan, in Hsian Fu, Huachou, Tungchou Fu, *Shensi*; Puchou Fu, *Shansi.* A mountain was displaced and a new mountain was formed on level ground. The land was fissured and water burst forth to form a small pond in which were many small fish. Many houses were destroyed and about 830,000 people were killed. Shocks were repeated several times each day and the ground did not come to rest for several days (B, 1556, January).
743	1558	Feb. 9.	*Shensi.*
744	1558	April 27.	Changping, Shuntien Fu, *Chihli.*
745	1558	June 16.	Puchou Fu, *Shansi.* The ground did not come to rest for three days, and each shock was followed by a loud noise.
746	1558	July 3.	Ditto.
747	1558	Nov. 22.	Huachou, Tungchou Fu, *Shensi.* Each shock was followed by a loud noise.
748	1558	Nov. 28.	Ditto.
749	1558	Dec. 4.	Huachou, Tungchou Fu, *Shensi.* Many houses were destroyed.
750	1559	Aug. 25.	Nanking, *Kiangsu.* Followed by a loud noise.
751	1560	May.	Chiahsing Fu, Huchou Fu, *Chehkiang.* Many fish jumped out of the river.
752	1561	Mar. 3.	Shantan in Kanchou Fu, *Kansu.* Many houses and castles were damaged.
753	1561	Aug. 16.	Taiyuan Fu, Tatung Fu, *Shansi*; Yulin Fu, *Shensi*; Ninghsia Fu and Kuyuan in Pingling Fu, *Kansu.* The greatest damage was done at Ninghsia and Kuyuan. Many houses were destroyed, and many people lost their lives.
754	1562	Feb. 24.	Imperial City, Peking, Ninghsia and Hosi, *Kansu.*
755	1566	Feb. 1.	Fuchou, Hsinghua, and Chuanchou, *Fuhkien.*
756	1568	April 11.	Hsian Fu, Hanchung Fu, *Shensi*; Chingyang Fu, Ninghsia, *Kansu*; Puchou Fu, Anyi, *Shansi*; also Yunyang, *Hupeh.*
757	1568	May 5.	Imperial City, Peking, Leting, Yungping Fu, *Chihli*; Tengchou, *Shantung*; Shunching, *Ssuchuan.* The greatest damage occurred at Leting. At two places the land opened for a length of 30 feet and water burst out of the cracks. The Castle of Ningyuen, in *Ssuchuan*, was destroyed.
758	1568	May 10.	Huaiching Fu, Nanyang Fu, Juning Fu, *Honan*, and Ninghsia, *Kansu.*
759	1568	May 12.	Fenghsiang Fu, Hsian Fu, *Shensi*; Pingling Fu, Chingyang Fu, *Kansu.* Many castles and houses were destroyed and many people were killed.
760	1569	Dec. 28.	Imperial City, Peking.
761	1570	May 15.	Ditto.
762	1571	July 3.	Imperial City, Peking. Shocks repeated three times during the day.

No.	Date. A.D.		
763	1573	Sept. 7.	Chingchou Fu, *Hupeh.*
764	1574	Mar. 21.	Changting in Tingchou Fu, *Fuhkien.* The land was cracked and many houses and people were buried.
765	1575	Feb.	Hukuang (comprising the present provinces of *Hunan* and *Hupeh*) and *Kiangsi.*
766	1575	June 19.	Hsiangyang Fu, Yunyang Fu, *Hupeh*, and Nanyang in *Honan.* There was a movement for three days.
767	1575	June.	Hsinyang, Juning, *Honan.*
768	1575	Aug. 7.	Fuchou Fu, Tingchou Fu, Changchou Fu, *Fuhkien*, and Haiyung, Chaochou Fu, *Kuangtung.*
769	1575	Nov. 5.	Imperial City.
770	1575	Nov. 15.	Ditto.
771	1575	Nov. 27.	Minchou in Kungchang Fu, *Kansu.* Shocks were repeated many times during the day.
772	1576	Mar. 26.	Su and Liaotung, *Shingking.*
773	1576	Mar. 27.	Ditto.
774	1577	Mar. 22.	Tengyueh in Yungchang Fu, *Yunnan.* During the day there were twenty shocks.
775	1577	Mar. 23.	The same district. A landslip took place; a mountain was displaced; water burst out; many people were killed.
776	1579	Aug. 16.	Imperial City, Peking.
777	1580	July 7.	Tsunhua, Yungping Fu, *Chihli.* For a week there were many shocks every day.
778	1580	Sept. 16.	Chingping, Pinglu, Pingyang Fu, *Shansi.* A thousand yards of the castle wall were destroyed.
779	1581	May 27.	Yuchou in Hsuanhua Fu, *Chihli*; Tatung Fu and neighbouring districts in *Shansi.* It was followed by a loud noise.
780	1583	Feb. 27.	Chengtien Fu (now Anlu Fu), *Hupeh.*
781	1584	Mar. 31.	Imperial City, Peking.
782	1584	June 27.	Ditto.
783	1585	Feb. 7.	Huaian Fu, Yangchou Fu, Chiangning Fu, *Kiangsu*, and Luchou, *Anhui.*
784	1585	April 6.	Shanyin in Tatung Fu, *Shansi.*
785	1585	Sept. 4.	Imperial City, Peking.
786	1586	May 27.	Ditto.
787	1587	April 10.	Kaifeng, Changte, Weihui, and Huaiching Fu, *Honan.* Three shocks during the day.
788	1587	June.	Taiyuan Fu, *Shansi.*
789	1588	July 1.	Imperial City, Peking.
790	1589	Aug. 24.	Hangchou Fu, Wenchou Fu, Shaohsing Fu, *Chehkiang.*
791	1590	July 7.	Kanchou and Lintao, *Kansu.* The damage was great, and it is impossible to estimate the same. Very many people were killed.
792	1590	Aug.	Fuchou Fu, *Fuhkien.* Very many shocks.
793	1591	April 27.	Changpingchou in Shuntien Fu, *Chihli.*
794	1591	Nov. 21.	Shantan in Kanchou Fu, *Kansu.*
795	1595	July 2.	Imperial City.
796	1596	Jan. 24.	Hsian Fu, in *Shensi*, where the shock was followed by a loud noise.
797	1596	Dec.	Fuchan, *Fuhkien.*
798	1597	Feb. 17.	Ssuchuan in Liaotang, *Shingking.* The ground was moving for three days.
799	1597	Oct. 2.	Liaoyang and Kuangning, *Shingking.* Water burst out of the ground, and it did not cease for three days.
800	1597	Oct. 6.	Imperial City, Peking, and neighbouring districts.
801	1598	Feb. 5.	Ditto.
802	1598	Feb. 6.	Ninghsia, *Kansu.*
803	1598	Feb. 7.	Changle in Yichang, *Hupeh.* There was a landslip 20 yards in depth.
804	1598	Sept. 24.	Imperial City. It was followed by a loud noise.
805	1599	Sept. 13.	Chengtien, Anlu Fu, Mienyang, in Hanyang Fu, *Huveh*; Yochou Fu, *Hunan.*

No.	Date. A.D.		
806	1600	Mar. 18.	Imperial City, Peking. The shocks were from north-east to south-west, and were repeated twice.
807	1602	May 30.	Shunghsiang in Anlu Fu, *Hupeh.* Many houses were destroyed.
808	1602	July 2.	Imperial City, Peking.
809	1604	Oct. 25.	Kungchang Fu, *Kansu*; Lechuan, Hsian Fu, *Shensi*; Paiyang in Kuanghsin Fu, *Kiangsi*; Wu in Suchou, *Kiangsu.* The shocks were repeated ten times in the day; many houses were destroyed and many people were killed. At Paiyang the ground opened for a length of ten yards and water burst out.
810	1605	July 14.	Luchuan in Yulin, *Kuangsi.* The shock was followed by a loud noise, city walls and houses were destroyed, and many were killed.
811	1605	Nov. 6.	Imperial City, Peking. The motion was from north-east to south-west.
812	1606	July 23.	Taiyuan Fu, *Shansi.*
813	1607	Sept. 16.	Sungpan, Lungan Fu, Mou, Wenchou, *Ssuchuan.* The ground moved for several days.
814	1608	Mar. 27.	Imperial City, Peking.
815	1608	Aug. 23.	Ditto.
816	1609	July 13.	Kanchou Fu, *Kansu.* Many city walls and houses were destroyed, and about 840 people were killed. At Tungkuan, Shaohsing Fu, *Chehkiang,* the land opened for a length of 870 li (about 310 miles).
817	1612	Mar. 12.	Tali, Wuting, and Chuching Fu, Yunnan Fu, *Yunnan.*
818	1612	Mar. 13.	Yunnan Fu and Chuching Fu, *Yunnan.*
819	1612	July 5.	Yunnan Fu and Chuching Fu, *Yunnan.* Many houses were destroyed.
820	1614	Oct. 24.	Taiyuan Fu, *Shansi,* and Honan Fu, *Honan.*
821	1615	Mar. 1.	Yangchou Fu, *Kiangsu,* and Langshan (now Changyang), Yichang Fu, *Hupeh.* In Langshan a temple was thrown out of the vertical.
822	1615	Aug. 24.	Chuhsiang Fu, *Yunnan.* The shock was followed by a loud noise and people were frightened.
823	1615	Dec. 8.	Imperial City, Peking.
824	1616	May	Hsinfeng Fu, Chenchiang Fu, *Kiangsu.* The ground did not come to rest for twenty-eight days.
825	1617	June 14.	Fengyang Fu, *Anhui.*
826	1617	June 15.	Ditto.
827	1618	Aug. 15.	Imperial City, Peking.
828	1618	Nov. 17.	Imperial City, Peking, Shenchih, Ningwu Fu, and seventeen other districts in *Shansi.*
829	1620	Mar. 5.	Yunnan Fu, *Yunnan*; Chaoching Fu, Huichou, *Kuangtung,* and Wuchang, and the whole of *Hupeh.*
830	1622	Mar. 18.	Tungchang, *Shantung*; Honan Fu, *Honan*; and Haining, Hangchou Fu, *Chehkiang.*
831	1622	April 17.	Tungchang and eight other districts in *Shantung.* Many people were killed and many houses destroyed; the movement did not cease for three days.
832	1622	Oct. 25.	Lungte and neighbouring districts in Pingliang, *Kansu.* It destroyed the city walls for a length of 30,000 yards; about 11,800 houses were damaged and about 12,000 people were killed or wounded.
833	1622	Dec. 13.	Hsian, *Shensi.*
834	1623	April 30.	Imperial City, Peking.
835	1623	Oct. 18.	Ditto.
836	1623	Dec. 23.	Yunnan Fu, *Yunnan.*
837	1624	Feb. 10.	Nanking and six other districts. The greatest damage was at Yangchou Fu, *Kiangsu.*
838	1624	Feb. 11.	Imperial City, Peking.
839	1624	Mar. 31.	Suchou. Shuntien Fu, and Yungping Fu, *Chihli.*

No.	Date. A.D.		
840	1624	April 17.	Leting in Yungping Fu and the neighbouring district of *Chihli*. The land opened and water burst out: it rose to a height of one foot.
841	1624	April 18.	Ditto.
842	1624	April 21.	Ditto.
843	1624	April 23.	Leting in Yungping Fu. There were three shocks in one day.
844	1624	July 20.	Paoting Fu, *Chihli*. City walls and houses were destroyed and many people were killed.
845	1624	Sept. 15.	*Shensi* (Hsian).
846	1625	Jan. 31.	Nanking.
847	1626	June 28.	Taming and Kuangping, *Chihli*; Tungchang Fu, *Shantung*; Honan Fu, *Honan*; and Pingyang, *Shansi*. The ground did not come to rest for several months: the damage was so great that it was impossible to find out how many houses were destroyed and how many people were killed.
848	1626	Aug. 22.	*Honan*.
849	1626	Oct. 24.	Fuchou, *Fuhkien*.
850	1627	Feb. 17.	Ninghsia, *Kansu*. A stone temple fell and killed many priests.
851	1627		Another shock at Nanking.
852	1627		Ninghsia. The shocks were followed by a loud noise; the ground did not come to rest for several months; there were about one hundred shocks; many buildings were destroyed and many people were killed.
853	1627	Nov. 27.	Nanking. The motion was from north-west to south-east, and it was followed by a loud noise.
854	1628	Oct. 7.	Imperial City, Peking.
855	1630	Oct. 27.	Nanking.
856	1631	July 22.	Lintao and Kungchang, *Kansu*. Many houses were destroyed and many people and cattle were killed.
857	1632	June 17.	Nanking and Chengtu, *Ssuchuan*.
858	1632	Nov. 4.	*Shansi* (Taiyuan).
859	1632	Dec. 31.	*Yunnan* (Yunnan).
860	1633	Aug. 12.	*Shensi* (Hsian).
861	1635		*Shansi* (Taiyuan).
862	1636	April 28.	*Fuhkien* (Fuchou).
863	1637	Jan. 31.	Nanking, *Kiangsu*.
864	1637	Sept. 5.	*Yunnan*.
865	1637	Dec. 7.	Chengtu, *Ssuchuan*.
866	1638	Jan.	Hsian Fu, *Shensi*. The ground did not come to rest for several months.
867	1638	Aug. 10.	Liaotung, *Shingking*.
868	1639	Mar. 9.	Imperial City, Peking.
869	1640	Dec. 23.	Nanking.
870	1641	April 12.	*Fuhkien* (Fuchou).
871	1641	May 30.	Changsha, *Hunan*, and *Hupeh* (Wuchang).
872	1641	June 22.	*Kansu* (Kungchang).
873	1641	July 9.	*Fuhkien* (Fuchou).
874	1641	Oct. 25.	*Ssuchuan* (Chengtu).
875	1642	June 15.	Kuangchou, *Kuangtung*, and Pingle, *Kuangsi*.
876	1642	Aug. 22.	*Shansi* (Taiyuan).
877	1643	Oct.	Fengyang in *Anhui*.
878	1643	Dec. 16.	*Shantung* (Chinan).
879	1644	Feb. 8.	Fengyang in *Anhui*.
880	1644	Feb. 9.	*Kuangtung* (Kuangchou).
881	1644	Mar. 5.	Nanking.
882	1676	July.	Peking and Tungchou (comprising Tung, Tsunhua, and Yungping), *Chihli*. Three thousand two hundred and fifty people were killed and the earthquake lasted three months.
883	1720	June 11.	9.45 A.M., at west of Peking. The castle Chacheng destroyed; one thousand people were killed. Shocks continued twenty days.

No.	Date. A.D.		
884	1730	Sept. 30.	Peking. About one thousand people were killed and shocks continued until October 8.
885	1817	Jan. 28.	3 A.M., Macao (Aomen) *Kuangtung*. Two shocks: it was strong at fifty leagues from Macao.
886	1824	Jan. 2.	Macao. Slight.
887	1824	Aug. 14.	Canton, *Kuangtung*. Great destruction and many lives lost.
888	1834		Yunnan Fu, *Yunnan*. The whole city was destroyed.
889	1834	June 28–July 19.	Changte Fu, *Honan*, and on the boundaries of three provinces, Kuangping Fu, Taming Fu, *Chihli*, Pingyang Fu, *Shansi*, and Tungchang Fu, *Shantung*. About forty thousand people were killed; ten thousand houses were destroyed.

The Distribution of Earthquake Destructivity in China.

In the following tables the numbers correspond to the numbers in the preceding catalogue. If a disturbance was severe at several places its number appears after several names. The earthquakes which are said to have shaken the whole of China took place between the years A.D. 600 and 788. At this time the Imperial City was Changan (present Hsian in Shensi). The province of Yunnan was not then included in China.

Imperial cities referred to were as follow :—

Changan, Hsian, Shensi, 206 B.C. to A.D. 25 and A.D. 589 to 907.
Honan (Loyang), Honan, A.D. 26 to 194 and 222 to 265.
Chengtu, Ssuchuan, A.D. 221 to 263.
Nanking, Kiangsu, A.D. 222 to 277 and 317 to 589 and 1268 to 1425.
Taiyuan, Shansi, A.D. 386 to 535.
Kaifeng, Honan, A.D. 907 to 1278.
Peking, Chihli, A.D. 1260 to 1368 and 1425 to present time.

Earthquakes at Unknown Places. (91 Entries.)

9, 12, 13, 15, 19, 21, 22, 23, 24, 30, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 49, 50, 51, 53, 70, 71, 76, 90, 91, 96, 104, 133, 135, 137, 138, 139, 142, 160, 161, 162, 163, 165, 170, 171, 173, 174, 175, 176, 178, 179, 180, 181, 182, 183, 184, 185, 186, 189, 190, 192, 193, 195, 196, 197, 212, 235, 275, 293, 382, 395, 399, 400, 401, 411, 435, 436, 428, 438, 439, 440, 450, 458, 481, 500, 614, 640, 641, 642—total, 91.

Earthquakes which Shook the Whole of China. (18 Entries.)

214, 255, 256, 257, 258, 259, 260, 261, 262, 264, 265, 266, 267, 268, 269, 270, 271, 272—total, 18.

Anhui. (33 Entries.)

Anching (lat. 30° 32′, long. 117° 07′), 504, 509, 511—total, 3.
Chu (lat. 32° 15′, long. 118° 20′), 380—total, 1.
Fengyang (lat. 32° 54′, long. 117° 35′), 310, 625, 633, 670, 697, 722, 723, 740, 825, 826, 877, 879—total, 12.
Luchou (lat. 31° 50′, long. 117° 15′), 509, 593, 633, 783—total, 4.
Ningkuo (lat. 30° 50′, long. 118° 41′), 545, 683—total, 2.
Taiping (lat. 31° 18′, long. 118° 21′), 109, 118, 119, 124, 125, 150, 151, 152, 683—total, 9.
Yingchou (lat. 32° 23′, long. 116° 30′), 633, 683—total, 2.

Chehkiang. (30 Entries.)

Chiahsing (lat. 30° 48′, long. 120° 43′), 354, 682, 751—total, 3.
Chinhua (lat. 29° 11′, long. 110° 51′), 708—total, 1.
Chuchou (lat. 28° 26′, long. 119° 57′), 553—total, 1.
Hangchou (lat. 30° 12′, long. 120° 12′), 299, 394, 682, 705, 790, 830—total, 6.

Huchou (lat. 30° 48′, long. 120° 3′), 119, 151, 152, 751—total, 4.
Ningpo (lat. 29° 49′, long. 121° 35′), 682—total, 1.
Shaohsing (lat. 29° 56′, long 120° 39′), 119, 151, 152, 547, 682, 790, 816—total, 7.
Taichou (lat. 28° 54′, long. 121° 06′), 536, 556—total, 2.
Tinghai (lat. 30° 01′, long. 122° 14′), 719—total, 1.
Wenchou (lat. 22° 47′, long. 120° 45′), 331, 524, 790—total, 3.
Yenchou (lat. 29° 27′, long. 119° 35′), 429—total, 1.

Chihli. (161 Entries.)

Chengte (lat. 40° 59′, long. 117° 59′), 209—total, 1.
Chengting (lat. 37° 38′, long. 115° 42′), 325, 336, 392, 496, 668—total, 5
Hochien (lat. 38° 33′, long. 116° 00′), 136, 328, 362, 364, 365, 693—total, 6.
Hsuanhua (lat. 40° 29′, long. 116° 03′), 127, 129, 512, 514, 516, 615, 636, 651, 684, 713, 779—total, 11.
Kuangping (lat. 36° 46′, long. 114° 55′), 315, 847, 889—total, 3.
Paoting (lat. 38° 53′, long. 115° 36′), 247, 300, 303, 355, 367, 387, 693, 737, 844—total, 9.
Shangtu (lat. 42° 15′, long. 116° 11′), 294, 296, 422, 423, 424, 448—total, 6.
Shunte (lat. 37° 07′, long. 114° 39′), 316, 676—total, 2.
Tsunhua (lat. 40° 11′, long. 117° 53′), 634, 635, 644—total, 3.
Shuntien, Peking (lat 39° 57′, long. 116° 29′), 355, 443, 444, 445, 470, 471, 472, 473, 486, 487, 498, 502, 506, 507, 512, 513, 515, 518, 521, 527, 549, 585, 589, 590, 591, 594, 597, 600, 601, 602, 603, 604, 606, 607, 609, 616, 624, 628, 634, 635, 636, 644, 645, 647, 654, 655, 659, 665, 666, 669, 670, 693, 698, 712, 713, 720, 726, 727, 728, 737, 738, 739, 744, 754, 757, 760, 761, 762, 769, 770, 776, 781, 782, 785, 786, 789, 793, 800, 801, 804, 806, 808, 811, 814, 815, 823, 827, 828, 834, 835, 838, 839, 854, 868, 882, 883, 884—total, 97.
Taming (lat. 36° 21′, long. 115° 22′), 676, 847, 889—total, 3.
Tientsin (lat. 39° 07′, long. 117° 11′), 315, 362, 368, 612—total, 4.
Yungping (lat. 39° 50′, long. 118° 50′), 315, 635, 636, 757, 777, 839, 840, 841, 842, 843, 882—total, 11.

Fuhkien. (42 Entries.)

Changchou (lat. 24° 31′, long. 117° 43′), 357, 672, 735, 768—total, 4.
Chienning (lat. 27° 04′, long. 118° 25′), 14, 116, 357—total, 3.
Chuanchou (lat. 24° 56′, long. 118° 51′), 357, 446, 447, 672, 708, 714, 735, 755—total, 8.
Fuhchou (lat. 26° 03′, long. 119° 25′), 563, 564, 580, 631, 672, 714, 735, 755, 768, 792, 797, 849, 862, 870, 873—total, 15.
Hsinghua (lat. 25° 25′, long. 119° 17′), 350, 557, 672, 714, 735, 755—total, 6.
Shaowu (lat. 27° 22′, long. 117° 33′), 357, 531—total, 2.
Tingchou (lat. 25° 45′, long. 116° 30′), 448, 764, 768—total, 3.
Yenping (lat. 26° 38′, long. 118° 18′), 554—total, 1.

Honan. (138 Entries.)

Changte (lat. 36° 07′, long. 114° 30′), 99, 316, 362, 476, 677, 787, 847, 889—total, 8.
Honan (lat. 34° 43′, long. 112° 28′), 16, 17, 20, 32, 33, 48, 52, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 67, 68, 69, 72, 73, 74, 75, 78, 79, 80, 81, 82, 88, 93, 95, 105, 106, 110, 115, 126, 130, 132, 153, 154, 253, 291, 307, 310, 316, 377, 479, 561, 633, 718, 720, 742, 820, 830, 847, 848—total, 59.
Hsu (lat. 34° 06′, long. 114° 00′), 352—total, 1.
Huaiching (lat. 35° 07′, long. 113° 00′), 362, 373, 476, 496, 538, 722, 723, 758, 787—total, 9.
Juning (lat. 33° 01′, long. 114° 21′), 144, 618, 758, 767—total, 4.
Kaifeng (lat. 34° 57′, long. 114° 33′), 131, 311, 314, 317, 322, 323, 324, 330, 339, 341, 344, 351, 356, 358, 359, 360, 361, 365, 371, 388, 396, 397, 398, 407, 408, 409, 410, 413, 414, 415, 416, 417, 418, 419, 420, 421, 431, 433, 476, 519, 522, 658, 677, 717, 722, 723, 787—total, 47.
Nanyang (lat. 33° 07′, long. 112° 34′), 28, 111, 131, 758, 766—total, 5.
Shan (lat. 34° 45′, long. 111° 03′), 253, 671—total, 2.
Weihui (lat. 35° 25′, long. 114° 16′), 362, 658, 787—total, 3.

Hunan. (21 Entries.)

Changsha (lat. 28° 12′, long. 112° 47′), 120, 121, 363, 617, 619, 620, 765, 871—total, 8.

Chenchou (lat. 28° 22′, long. 110° 09′), 136—total, 1.

Hengchou (lat. 26° 55′, long. 112° 23′), 255, 256, 257, 258, 259, 260, 261, 262—total, 8.

Yochou (lat. 29° 18′, long. 113° 02′), 348, 391, 618, 805—total, 4.

Hupeh. (47 Entries.)

Anlu (lat. 31° 07′, long. 112° 39′), 539, 780, 805, 807—total, 4.

Chingchou (lat. 30° 27′, long. 112° 05′), 127, 140, 148, 167, 327, 329, 491, 539, 763—total, 9.

Hanyang (lat. 32° 32′, long. 114° 14′), 526, 618, 805—total, 3.

Hsiangyang (lat. 32° 06′, long. 113° 05′), 140, 611, 766—total, 3.

Huangchou (lat. 30° 26′, long. 114° 54′), 509—total, 1.

Wuchang (lat. 30° 33′, long. 114° 27′), 144, 145, 217, 508, 617, 618, 619, 620, 689, 703, 765, 829, 871—total, 13.

Yichang (lat. 30° 49′, long. 111° 10′), 145, 539, 803, 821—total, 4.

Yunyang (lat. 32° 49′, long. 110° 52′), 255, 256, 257, 258, 259, 260, 261, 262, 756, 766—total, 10.

Kansu. (117 Entries.)

Chingyung (lat. 36° 03′, long. 107° 43′), 318, 320, 375, 541, 567, 622, 671, 756, 759—total, 9.

Hosi (lat. 39 00′, long. 106° 00′), near Ninghsia, 244, 754—total, 2.

Hsining (lat. 36° 39′, long. 101° 48′), 430, 434, 437—total, 3.

Kanchou (lat. 39° 00′, long. 100° 56′), 89, 232, 244, 468, 627, 731, 752, 791, 794, 816—total, 10.

Kungchang (lat. 34° 56′, long. 104° 44′), 10, 11, 18, 20, 31, 34, 57, 62, 97, 98, 100, 144, 242, 313, 333, 462, 491, 499, 503, 517, 542, 566, 567, 626, 643, 731, 732, 733, 771, 809, 856, 872—total, 32.

Lanchou (lat. 36° 08′, long. 103° 55′), 62, 134, 374, 389, 542, 580—total, 6.

Liangchou (lat. 37° 59′, long. 102° 48′), 66, 79, 164, 168, 172, 211, 541, 542, 605, 627, 668—total, 11.

Lintao (lat. 39° 40′, long. 98° 20′), 567, 626, 791, 856—total, 4.

Lingpei (lat. 42° 00′, long. 99° 00′), 482, 484, 490—total, 3.

Ninghsia (lat. 38° 33′, long. 106° 08′), 107, 220, 318, 464, 467, 469, 489, 492, 493, 579, 585, 627, 657, 660, 668, 681, 732, 753, 754, 756, 758, 802, 850, 852—total, 24.

Pingliang (lat. 35° 35′, long. 106° 41′), 333, 374, 432, 541, 542, 643, 732, 733, 753, 759, 832—total, 11.

Suchou (lat. 39° 46′, long. 99° 07′), 237, 244—total 2.

Kiangsi. (16 Entries.)

Chian (lat. 27° 02′, long. 115° 05′), 145, 169, 188, 353—total, 4.

Chiuchiang (lat. 29° 42′, long. 116° 08′), 187, 188, 765—total, 3.

Chuanhsi (lat. 27° 34′, long. 118° 28′), 705—total, 1.

Fuchou (lat. 27° 56′, long. 116° 18′), 705—total, 1.

Jaochou (lat. 28° 59′, long. 116° 46′), 505, 510—total, 2.

Juichou (lat. 28° 25′, long. 115° 14′), 514—total, 1.

Kuanghsin (lat. 28° 28′, long. 118° 06′), 809—total, 1.

Nankang (lat. 29° 23′, long. 116° 10′), 188, 675, 676—total, 3.

Kiangsu. (107 Entries.)

Changchou (lat. 31° 47′, long. 119° 56′), 147, 236, 319, 683, 721—total, 5.

Chenchiang (lat. 32° 10′, long. 119° 21′), 109, 118, 119, 124, 125, 147, 237, 528, 535, 683, 824—total, 11.

Chiangning (Nanking) (lat. 32° 05′, long. 118° 47′), 92, 94, 95, 101, 112, 118, 159, 177, 191, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 570, 577, 578, 584, 586, 587, 588, 592, 595, 596, 597, 598, 599, 608, 610, 623, 633, 656, 659, 664, 665, 670, 673, 674, 679, 680, 683, 703, 718, 720, 721, 750, 783, 837, 846, 851, 853, 855, 857, 863, 869, 881—total, 62.

Haichou (lat. 34° 29′, long. 119° 27′), 662, 663—total, 2.

Hsuchou (lat. 34° 11′, long. 117° 32′), 310, 676, 722, 723—total, 4.

Huaian (lat. 33° 25′, long. 119° 22′), 546, 558, 633, 656, 683, 783—total, 6.

Suchou (lat. 31° 28′, long. 120° 44′), 147, 237, 378, 683, 721, 809—total, 6.

Sungchiang (lat. 31° 03′, long. 121° 15′), 683—total, 1.

Yangchou (lat. 32° 21′, long. 119° 15′), 166, 237, 239, 338, 633, 656, 683, 783, 821, 837—total, 10.

Kuangsi. (9 Entries.)

Pingle (lat. 24° 8′, long. 111° 17′), 122, 123, 568, 730, 875—total, 5.

Taiping (lat. 22° 25′, long. 107° 07′), 629—total, 1.

Wuchou (lat. 23° 29′, long. 110° 51′), 568, 646—total, 2.

Yulin (lat. 22° 43′, long. 109° 45′), 810—total, 1.

Kuangtung. (20 Entries.)

Chaoching (lat. 23° 05′, long. 112° 30′), 485, 738, 829—total, 3.

Chaochou (lat. 23° 34′, long. 116° 36′), 357, 369, 768—total, 3.

Chenchou (lat. 24° 40′, long. 116° 30′), 309—total, 1.

Huichou (lat. 23° 02′, long. 114° 13′), 829—total, 1.

Kuangchou (lat. 23° 08′, long. 111° 17′). 120, 121, 347, 580, 875, 880, 887—total, 7.

Leichou (lat. 20° 52′, long. 109° 40′), 550—total, 1.

Lienchou (lat. 21° 39′, long. 108° 59′), 646—total, 1.

Macao, or Aomen (lat. 22° 12′, long. 113° 30′) 885, 886—total, 2

Nanhsiung (lat. 25° 26′, long. 113° 52′), 555—total, 1.

Kueichou. (4 Entries.)

Hsingyi (lat. 25° 15′, long. 106° 00′), 661, 674, 724, 725—total, 4.

Shansi. (182 Entries.)

Chiang (lat. 35° 37′, long. 111° 29′), 240, 297, 298, 337, 684—total, 5.

Fenchou (lat. 37° 19′, long. 111° 41′), 240, 538, 543, 544, 559, 560, 565—total, 7.

Hsi (lat. 36° 40′, long. 110° 56′), 253, 474, 475, 477, 494, 495, 501, 565—total, 8.

Hsin (lat. 38° 26′, long. 112° 43′), 228, 338, 340, 342, 343, 345, 346, 538, 560—total, 9.

Luan (lat. 36° 07′, long. 113° 13′), 668, 677—total, 2.

Ningwu (lat. 39° 15′, long. 112° 00′), 828—total, 1.

Pingyang (lat. 36° 06′, long. 111° 33′), 77, 83, 84, 85, 86, 87, 106, 221, 222, 223, 224, 225, 226, 227, 240, 308, 318, 402, 403, 404, 405, 406, 425, 426, 427, 449, 453, 454, 456, 459, 466, 478, 534, 538, 540, 671, 677, 732, 778, 847, 889—total, 41.

Puchou (lat. 34° 54′, long. 100° 15′), 77, 83, 84, 85, 86, 87, 106, 155, 156, 157, 158, 221, 222, 223, 224, 225, 226, 227, 253, 276, 298, 307, 308, 318, 402, 403, 404, 405, 406, 463, 464, 534, 671, 673, 684, 742, 745, 746, 756—total, 39.

Soping (lat. 40° 10′, long. 112° 13′), 294, 615—total, 2.

Tatung (lat. 39° 39′, long. 113° 14′), 337, 455, 457, 615, 678, 699, 753, 779, 784—total, 9.

Taichou (lat. 39° 06′. long. 112° 58′), 334, 340, 342, 372, 386, 637—total, 6.

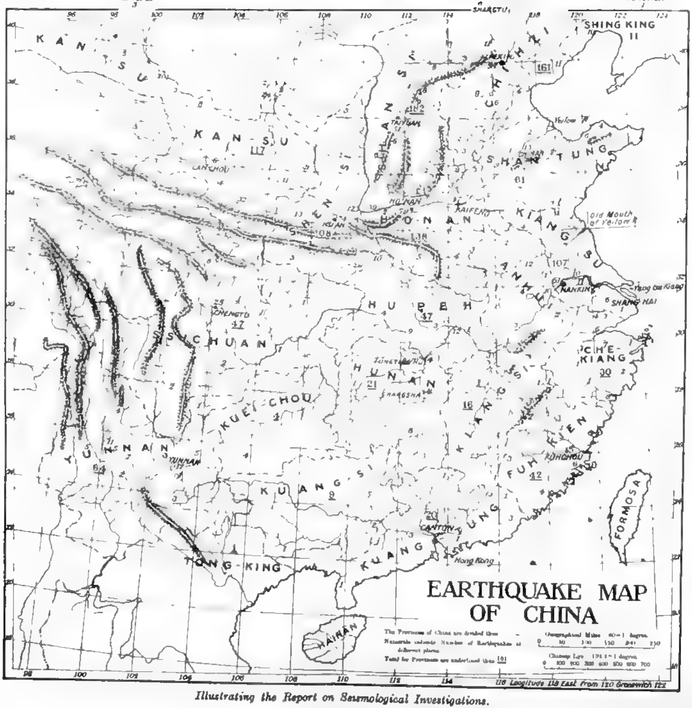
Taiyuan (lat. 37° 54′, long. 112° 31′), 8, 146, 177, 210, 295, 297, 298, 305, 312, 340, 342, 376, 381, 384, 385, 386, 453, 456, 459, 465, 478, 480, 520, 537, 538, 548, 551, 560, 565, 569, 571, 572, 573, 574, 575, 576, 585, 666, 668, 699, 720, 734, 736, 741, 753, 788, 812, 820, 858, 861, 876—total, 51.

Tsechou (lat. 35° 30′, long. 112° 50′), 82, 677—total, 2.

Shantung. (61 Entries.)

Chinan (lat. 36° 40′, long. 117° 1′), 1, 526, 528, 532, 533, 562, 583, 586, 707, 717, 718, 720, 878—total, 13.

Chining (lat. 36° 50′, long. 116° 58′), 705—total, 1.



Illustrating the Report on Seismological Investigations.

Chingchou (lat. 36°
total, 7
Laichou (lat. 37° 10
Taian (lat. 36° 10
Tengchou (lat.
Tsaochou (lat.
Tungchang (lat.
—total, 9
Wuting (lat. 37
Yenchou (lat.
Yichou (lat. 35°

Fenghsiang (lat.
733, 750—total, 14
Hanchung (lat.
Hsian (lat. 34° 1
241, 243
270, 271, 272
280, 292
776, 779
Suite (lat.
Tungchou (lat. 34
747, 748, 749—total
Yenan (lat. 36° 4
Yulin (lat. 38° 18

Fengtien (lat. 4
Liaotung, or Ch
778, 798, 799, 867

Chengtu (lat. 3
326, 332, 379, 393,
Chiating (lat. 2
Hsuchou (lat. 2
Lungan (lat. 3
total, 8
Mou (lat. 31° 4
Paoning (lat. 3
Ningyuan (lat
Shunching (lat
Chungching (l
Suiting (lat. 31
Tungchuan (la

Jihnan (lat. 21

Chaotung (lat
Chengchiang
Chingtung (la
Chuhsiung (la
Chuching (lat
Lichiang (lat.
Linan (lat. 2
Menghua (lat

Chingchou (lat. 36° 44′, long. 118° 44′), 349, 529, 530, 532, 534, 552, 707—total, 7.
Laichou (lat. 37° 10′, long. 126° 10′), 17, 523, 529, 532, 687, 707—total, 6.
Taian (lat. 36° 10′, long. 117° 15′), 29, 362, 526, 527, 533, 638, 639—total, 7.
Tengchou (lat. 37° 45′, long. 120° 42′), 350, 707, 738, 757—total, 4.
Tsaochou (lat. 35° 20′, long. 115° 35′), 301, 676—total, 2.
Tungchang (lat. 36° 37′, long. 116° 12′), 310, 383, 658, 676, 717, 830, 831, 847, 889—total, 9.
Wuting (lat. 37° 32′, long. 117° 41′), 667, 693—total, 2.
Yenchou (lat. 35° 47′, long. 116° 59′), 29, 141, 194, 526, 533, 633, 676—total, 7.
Yichou (lat. 35° 15′, long. 118° 35′), 380, 525, 627—total, 3.

Shensi. (108 Entries.)

Fenghsiang (lat. 34° 35′, long. 107° 50′), 2, 3, 4, 5, 6, 7, 79, 215, 491, 648, 671, 733, 759—total, 13.
Hanchung (lat. 32° 56′, long. 107° 12′), 491, 648, 756—total, 3.
Hsian (lat. 34° 17′, long. 108° 58′), 26, 27, 141, 143, 213, 216, 218, 229, 230, 231, 233, 234, 241, 243, 245, 246, 248, 249, 250, 251, 252, 254, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 276, 277, 278, 279, 280, 282, 283, 284, 285, 286, 287, 288, 289, 290, 292, 294, 302, 304, 318, 373, 374, 390, 488, 565, 566, 671, 718, 720, 733, 742, 743, 756, 759, 796, 809, 833, 845, 860, 866—total, 74.
Suite (lat. 37° 38′, long. 110° 03′), 386—total, 1.
Tungchou (lat. 34° 50′, long. 109° 51′), 370, 402, 403, 404, 405, 406, 671, 685, 742, 747, 748, 749—total, 12.
Yenan (lat. 36° 42′, long. 109° 28′), 460, 461—total, 2.
Yulin (lat 38° 18′, long. 109° 33′), 627, 668, 753—total, 3.

Shingking. (11 Entries.)

Fengtien (lat. 41° 10′, long. 123° 27′), 799—total, 1.
Liaotung, or Chinchou (lat. 41° 06′, long. 121° 18′), 127, 483, 497, 635, 636, 772, 773, 798, 799, 867—total, 10.

Ssuchuan. (47 Entries.)

Chengtu (lat. 30° 41′, long. 103° 11′), 102, 103, 107, 108, 113, 128, 238, 306, 321, 326, 332, 379, 393, 441, 491, 613, 630, 649, 650, 652, 653, 696, 857, 865, 874—total, 25.
Chiating (lat. 29° 28′, long. 103° 55′), 25, 113, 114, 442—total, 4.
Hsuchou (lat. 28° 38′, long. 104° 46′), 366, 699—total, 2.
Lungan (lat. 32° 33′, long. 103° 36′), 107, 108, 113, 117, 149, 219, 442, 813—total, 8.
Mou (lat. 31° 40′, long. 106° 15′), 813—total, 1.
Paoning (lat. 31° 32′, long. 105° 59′), 318—total, 1.
Ningyuan (lat. 27° 50′, long. 102° 12′), 335, 632—total, 2.
Shunching (lat. 30° 49′, long. 106° 08′), 757—total, 1.
Chungching (lat 29° 42′, long. 106° 42′), 696—total, 1
Suiting (lat. 31° 27′, long. 107° 51′), 412—total, 1.
Tungchuan (lat. 31° 9′, long. 105° 11′), 696—total, 1.

Tongking. (1 Entry.)

Jihnan (lat. 24° 26′, long. 108° 25′), 330.

Yunnan. (64 Entries.)

Chaotung (lat. 27° 20′, long. 103° 50′), 462—total, 1.
Chengchiang (lat. 24° 42′, long. 103° 04′), 706—total, 1.
Chingtung (lat. 24° 31′, long. 101° 4′), 704, 716—total, 2.
Chuhsiung (lat. 25° 06′, long. 101° 43′), 690, 691, 694, 704, 715, 730, 822—total, 7.
Chuching (lat. 25° 32′, long. 103° 50′), 659, 700, 817, 818, 819—total, 5.
Lichiang (lat. 26° 52′, long. 100° 27′), 281, 621, 692, 715—total, 4.
Linan (lat. 24° 18′, long. 103° 5′), 326, 706, 730—total, 3.
Menghua (lat. 25° 18′, long. 100° 30′), 704, 709, 710, 711, 715—total, 5.

Tali (lat. 75° 44′, long. 100° 22′), 692, 700, 701, 702, 704, 709, 710, 711, 715, 817, 818, 819—total, 11.

Wuting (lat. 25° 32′, long. 102° 33′), 817, 818, 819—total, 3.

Yunnan (lat. 25° 06′, long. 102° 52′), 451, 452, 581, 582, 686, 688, 700, 715, 729, 817, 818, 819, 829, 836, 859, 864, 888—total, 17.

Yungchang (lat. 25° 05′, long. 99° 26′), 695, 724, 725, 774, 775—total, 5.

Monthly and Seasonal Distribution of Earthquakes.

Warm Season						Cold Season						With Date of Year only	Total
Spring			Summer			Autumn			Winter				
Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.		
78	66	72	65	67	67	66	62	60	65	68	77	76	889
216			199			188			210			—	—
415						398						—	—

Dynamic Isomerism.—Report of the Committee, consisting of Professor H. E. ARMSTRONG (*Chairman*), Dr. T. M. LOWRY (*Secretary*), Professor SYDNEY YOUNG, Dr. C. H. DESCH, Dr. J. J. DOBBIE, Dr. M. O. FORSTER, *and* Dr. A. LAPWORTH. (*Drawn up by the Secretary.*)

A.—SINCE the appearance of the last report the experiments on the influence of acids, bases, and salts in accelerating isomeric change in solutions of nitrocamphor have been completed and published.[1]

B.—CARBONYL CHLORIDE AS AN AGENT FOR ARRESTING ISOMERIC CHANGE.

The most important feature of the year's work has been the discovery of a group of agents by means of which the isomeric change of nitrocamphor can be retarded or completely arrested. As long ago as 1899 [2] it was observed that solutions of nitrocamphor in chloroform behaved in an abnormal manner in that isomeric change was sometimes arrested during a period of one or two weeks and then abruptly started by some slight change of conditions, *e.g.*, by transferring the solution from a flask to a polarimeter tube.

The abnormal properties of this solvent were again noticed in the recent experiments on the influence of acids and bases. The basic chloroform solutions showed a marked decrease of activity when kept for a few days, whilst dilution produced a loss of catalytic power out of

[1] Lowry and Magson, 'The Influence of Nitrocamphor on the Mutarotation of Nitrocamphor,' *Trans. Chem. Soc.*, 1908, **93**, 107–119

[2] Lowry, *Trans. Chem. Soc.*, 1899, **75**, 211.

all proportion to the decreased concentration of the base. In one extreme case the isomeric change in a solution to which a trace of piperidine had been added practically ceased at the end of a fortnight, although the final condition of equilibrium had not by any means been reached. The more concentrated acid solutions produced an acceleration of isomeric change, but a retardation was noticed when smaller concentrations were used : in one case the rotatory power of the solution remained absolutely constant during a period of twenty-four days.

The earliest observations of arrested isomeric change had led to the conclusion that in non-oxygenated solvents the change was conditioned by the presence of a third substance, probably a basic impurity. The retardation produced by the acid chloroform solutions could not be attributed to mere neutralisation, since an acceleration was observed when benzene was used as the solvent. It was noticed, however, that the chloroform solutions acquired a pungent and unpleasant odour, which was ultimately traced to the formation of carbonyl chloride by oxidation of the chloroform $CHCl_3 + O = COCl_2 + HCl$; to this substance the curious behaviour of the chloroform solutions was undoubtedly due.

The action of the chloride probably depends on its power of converting ammonia and bases such as piperidine into neutral carbamides

$$COCl_2 + 2NH_3 = 2HCl + CO(NH_2)_2$$
$$COCl_2 + 2NC_5H_{11} = 2HCl + CO(NC_5H_{10})_2.$$

It was found that the chloride was capable of retarding or arresting the isomeric change of nitrocamphor dissolved in benzene or in ether, and that acetyl chloride produced a similar effect in benzene and in carbon disulphide. Phenyl-carbimide did not retard the isomeric change of nitrocamphor dissolved in benzene, and acetyl chloride proved inefficient when added to a solution in acetic acid. In the latter case it is probable that the solvent has itself a catalytic action, and this may also be true when water and alcohol are used. The bearing of these observations on the problem of chemical change has been discussed elsewhere.[1]

C.—Relationship between Absorption Spectra and Isomeric Change.

As the result of a series of experiments on the absorption spectra of substances of the ethyl aceto-acetate group, Baly and Desch [2] were led to the conclusion that there was a close relationship between the absorption bands which appeared in the spectra of some of these compounds and the property which they possess of undergoing reversible isomeric change. In view of the importance of this hypothesis in relation to the subject of dynamic isomerism it was thought to be desirable to test it in the case of a number of optically active compounds. These have the advantage that many of them can be crystallised out in a pure enolic or in a pure ketonic form, that it is possible by means of polarimetric observations to determine the actual velocity with which they undergo isomeric change, and that in a number

[1] *Trans. Chem. Soc.*, 1908, **93**, 119–132.
[2] *Ibid.*, 1904, **85**, 1029; 1905, **87**, 766.

of cases the proportions in which the isomerides are in equilibrium can be determined by means of solubility measurements. Photographs have therefore been taken of the absorption spectra of the majority of the camphor-derivatives which have formed the subject of previous investigations, and we are now in a position to summarise the principal results that have been obtained.

Halogen-derivatives of Camphor.

(1) The camphor band observed by Baly and by Hartley at a concentration of N|10 practically disappears when the concentration of the alcoholic solution is reduced to N|100 (thickness of liquid 250 to 2·5 mm.), but can be restored by the addition of alkali. β-Bromocamphor,

$$C_8H_{13}Br\left\langle\begin{array}{l}CH_2\\ |\\ CO,\end{array}\right.$$

at a concentration of N|100 behaves in the same way as camphor.

(2) α-Chlorocamphor and α-bromocamphor at a concentration of N|100 show a band in the same position $\left(\frac{1}{\lambda}\ 3400\right)$ as the camphor band. The band is eliminated when the second α-position is occupied by bromine or by a nitro group, but remains unaffected when the halogen is introduced in the β or in the π position.

(3) No marked change in persistence is produced by the addition of alkali to α-chlorocamphor, α-bromocamphor, or their β and π bromoderivatives. All these compounds are quite stable when alone, but undergo isomeric change rapidly in presence of a small proportion of alkali. It is therefore evident that in this case at least there is no direct quantitative relationship between the velocity of isomeric change and the persistence of the absorption band.

Nitro-derivatives.

(4) Nitrocamphane shows no absorption band, whether the solution be prepared by dissolving the crystals of the normal form or by adding acid to the sodium salt of the pseudo form. Even in presence of ten equivalents of alkali no definite band is developed. It is therefore clear that dynamic isomerism, even of a well-pronounced type, is not necessarily associated with the production of a band.

(5) Nitrocamphor dissolved in alcohol shows a shallow band at $\frac{1}{\lambda}$ 3000; it differs in position from that produced by bromocamphor—a result that is in accord with the view, consistently advocated, that the mobile hydrogen atom in this compound wanders to the nitro and not to the carbonyl group. The band disappears in the α-chloro and α-bromo derivatives, and also in the anhydride derived from the pseudo form by loss of water; its occurrence appears, therefore, to be limited by the same conditions as those which determine the occurrence of isomeric change.

(6) In marked contrast with the behaviour of the —CHX·CO— compounds described above, the nitrocamphor band is enormously inten-

sified by the addition of alkalies. This result is, perhaps, associated in some way with the fact that nitrocamphor forms a stable sodium salt whilst bromocamphor does not.

(7) Camphoryl oxime—the isomer of nitrocamphor—resembles it in giving a very intense band in presence of alkalies, although the head of the band occurs at a considerably smaller wave-length $\left(\frac{1}{\lambda}\ 3650\right)$. The band does not appear in solutions of the oxime alone, and is not given by the acetyl derivative. Camphoric anhydride, the parent-substance from which the oxime is derived, is very diactinic and shows no band.

Sulphonic-derivatives of Camphor.

(8) β and π sulphonic derivatives containing the group

$$Y\cdot SO_2\cdot C_8H_{13}\left<\begin{array}{l}CHX\\ \ |\\ CO\end{array}\right.$$

usually show an absorption band, but this does not appear in camphor-β-sulphonamide and some of its derivatives. The replacement of both α-hydrogen atoms by halogens causes the band to disappear.

D.—Camphorcarboxylic Acid.

Investigations of the mutarotation phenomena and absorption spectra of camphorcarboxylic acid and its derivatives are in progress, but as the work is not yet complete it is proposed to reserve the discussion for a subsequent report.

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. *Transformation of Nitroaminobenzenes into Nitroanilines.* (With W. W. Reed, M.Sc., A.I.C.)

The investigation of the transformation of 2·4-dichloro-1-nitroaminobenzene into 2 : 4-dichloro-6-nitroaniline, reported on last year (Reports, 1907, p. 101) has been continued.

Transformation of the Crystalline Nitroamine.

The object of the new experiments on the transformation of the crystalline nitroamine was to determine with greater accuracy the limiting value of the pressure of the gaseous catalyst, below which no transformation occurred. The method employed was substantially that described in last year's report, but more elaborate methods were used for determining the partial pressure of the reagent, hydrogen chloride. The form of the experimental tube was so modified that, after the change had occurred (or failed to occur), the tube could be opened, attached to a Sprengel pump, and its exact volume measured by collecting the air filling it at a given temperature and pressure. The hydrogen chloride was introduced as dilute standardised solutions, known weights of which were used. A series of such experiments has shown that at 13° the hydrogen chloride must be at a pressure of 14 mm. of mercury for a change to take place.

Transformation of the Nitroamine in Solution.

Inasmuch as the nitroamine is colourless, whilst the nitroaniline is intensely coloured, the change can be quantitatively followed by comparing the colour of the solution, during the course of the transformation, with that of standard solutions of the nitroaniline. The method is exceedingly delicate; with practice it is easy to detect the difference in tint between 49 and 50 c.c. of a solution of nitroaniline containing 0·000225 gram in 100 c.c. when the tint of these volumes is compared in columns 12 cm. in length; that is, 0·00225 milligram of the aniline can be measured.

The low solubility of the nitroaniline (100 c.c. at 14° dissolve 0·0022 gram) allows only of the use of solutions of the nitroamine containing 0·003 gram per 100 c.c. in these experiments.

The measurements of the speed of transformation show that the reaction is one of the first order. The change into the nitroaniline is accompanied by a conversion (reduction) of the nitroamine into diazonium salt to the extent of 30 per cent. This fact only permits of the determination of an apparent value of the velocity coefficient.

(i) *Solvent.*—The only solvents which could be used were water, acetic acid, or mixtures of these. Alcohol and acetone, which are solvents of the catalysts, react with the nitroamine.

As the proportion of the acetic acid in the solvent is increased the rate of change slowly rises until, with 74 per cent. acetic acid, the rate is double that in pure water. But the use of higher concentrations of acetic acid is followed by a rapid rise in the speed of the change, which in glacial acetic acid is several hundred times as great as in water.

(ii) *Nature of the Acid* (*Catalyst*).—The efficacy of acids as catalysts in this transformation is roughly in the order of their activities as measured by other reactions. Nevertheless, chloric and perchloric acids appear to bring about the change twice as rapidly as hydrochloric acid, although they are somewhat less active as catalytic accelerators in hydrolyses, &c. The reduction of the nitroamine to diazo-compound is, however, much less in the case of these acids, a fact which may account for the more rapid formation of nitroaniline.

Hydrobromic and hydriodic acids reduce the nitroamine; the former reacts quantitatively according to the equation,

$$Ar.NH.NO_2 + 3HBr = Ar.N_2Br_3 + 2H_2O,$$

the diazonium perbromide crystallising out when acetic acid is the solvent. Hydriodic acid carries the reduction further.

(iii) *Concentration of the Acid.*—The effect of the concentration of the acid catalyst on the rate of change has been carefully tested with several acids both in aqueous and acetic acid solution.

In aqueous solution the rate is proportional to the square of the concentration of the acid—that is, on doubling the concentration of the acid the velocity is quadrupled.

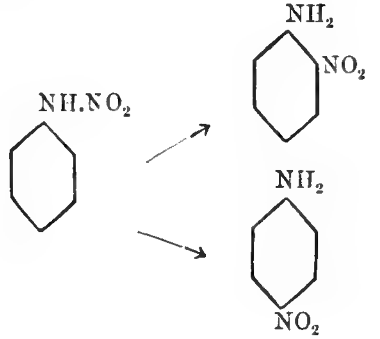
In acetic acid solution this proportionality does not hold, the increase of velocity being less for given increases of concentration of acid. For example, the ratio of the velocity coefficients for N/10 and N/20 H_2SO_4 in glacial acetic acid at 25° is $k_{N/10} : k_{N/20} = 2{\cdot}14$ instead of 4.

(iv) *Effect of Temperature.*—Within a range of temperature of 0–35° the products of the transformation of the nitroamine were not modified. When the nitroamine was melted under water or other solvents, a more profound decomposition was observed accompanied by oxidation of the benzene nucleus.

In aqueous solution the rate of the transformation was greatly increased by a rise of temperature. At 25° the rate of change is approximately thirty times as great as at 0°; the ratio of the velocity coefficients, when 2N HCl is the catalyst, at 25° and 35° C. is $k_{35°} : k_{25°} = 0{\cdot}002488/0{\cdot}00108 = 2{\cdot}3$.

Experiments on Nitroaminobenzene, $C_6H_5.NH.NO_2$.

A number of preliminary experiments have been made with the unsubstituted nitroaminobenzene. In its main features the molecular rearrangement of this nitroamine resembles that of its dichloro-derivative, but it is complicated by the simultaneous formation of both *o*- and *p*-nitroaniline—



Experiment has shown that the latter is only formed to the extent of some 10 per cent., but the difference in the intensity of the colours of the solutions of the nitroanilines has so far made any accurate measurement of the rate of change impossible by the method above described. Under like conditions (temperature and concentration of catalyst) the velocity is about one and a half times greater in the case of the unsubstituted than with the dichloro-compound; in glacial acetic acid, however, the change was roughly ten times as rapid.

Reduction to the diazo-compound also takes place, and since in this case the diazo-compound is unstable, the subsequent decomposition introduces another factor, which prevents quantitative measurements of the velocity.

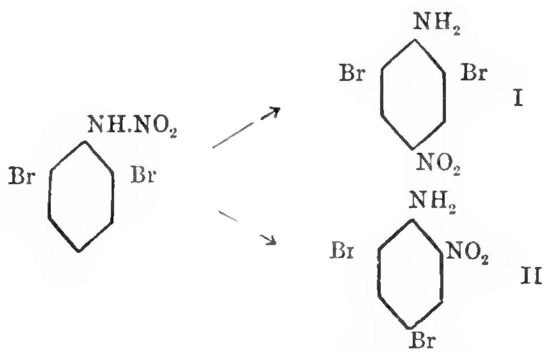
The views expressed in last year's report are confirmed by these more extended observations. The most simple interpretation of the facts seem to be that the catalyst (the acid) and the nitroamine form an additive compound, which alone is capable of molecular rearrangement.

For what reason the speed of the transformation should be proportional to the second power of the concentration of the acid is not very obvious. Blanksma[1] observed that the rate of the analogous transformation of acetylchloroaminobenzene into *p*-chloroacetanilide bore the same relation to the concentration of the hydrogen chloride, which is the only catalytic accelerator of this change. Acree[2] has suggested that the existence of the additive compound of the chloroamine and the catalyst is conditioned by the equilibrium: $Ar.NClAc,HCl \rightleftarrows Ar.NCl.Ac + H' + Cl'$, when the concentration of the complex would depend on the square of the concentration of the acid. That the ratios of the accelerating effects of hydrochloric, nitric, and sulphuric acids, $k_{HCl} : k_{HNO_3} : k_{H_2SO_4} = 1 : 1 : 2/3$, are approximately in the ratio of their ionisation in normal solutions is in harmony with this view.

II. *The Wandering of Bromine in the Transformation of Nitroaminobromobenzenes.*

(With C. PEARSON, B.Sc.)

In the transformation of 2 : 6-dibromo-1-nitroaminobenzene, in all circumstances when such a change will take place, we have observed a remarkable rearrangement of the points of attachment of the substituting groups.



Not only is the normal product, 2 : 6-dibromo-4-nitroaniline, I, in which the nitro group passes to the vacant para-position formed, but also 2 : 4-dibromo-6-nitroaniline, II. In the production of the latter compound, the migrating nitro group displaces one ortho-placed bromine atom, which then becomes attached to the para-carbon atom.

The direct nitration of 2 : 6-dibromoacetanilide is not accompanied by any such rearrangement; the nitro group only enters the para-position.

[1] *Recueil des Trav. Chim.*, 1903, **22**, 290.
[2] *Amer. Chem. Jour.*, 1907, **38**, 258.

Wave-length Tables of the Spectra of the Elements.—Report of the Committee, consisting of Sir H. E. ROSCOE (*Chairman*), Dr. MARSHALL WATTS (*Secretary*), Sir NORMAN LOCKYER, Professors Sir JAMES DEWAR, G. D. LIVEING, A. SCHUSTER, W. N. HARTLEY, *and* WOLCOTT GIBBS, Sir W. DE W. ABNEY, *and* Dr. W. E. ADENEY, *appointed to prepare a New Series of Wave-length Tables of the Spectra of the Elements.*

TANTALUM.

Rütten and Morsch, 'Zeitschrift für wissenschaftliche Photographie,' iii. 181 (1905).

Exner and Haschek, 'Sitzungsber. kais. Akad. Wissensch. Wien,' cvii. (IIa.), p. 813.

Exner and Haschek, 'Wellenlängen-Tabellen der Bogenspektren der Elemente.'

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
5780·858		1			1·58	4·7	17293·8
76·908		1n			1·57	,,	17305·6
5699·417		<1			1·55	4·8	17540·9
88·338		<1			,,	,,	75·0
65·054		5			1·54	,,	17647·3
46·077		4			,,	,,	17706·6
40·364		1			,,	,,	24·5
20·845		1			1·53	,,	86·1
5599·581		1			,,	4·9	17853·6
48·356		1			1·51	,,	18018·5
19·113		2			,,	,,	18114·0
01·084		<1			1·50	5·0	73·2
5499·691		1n			,,	,,	77·8
95·004		1			,,	,,	93·3
90·231		1			,,	,,	18209·2
61·498		2			1·49	,,	18305·0
58·584		<1			,,	,,	14·8
35·471		1			1·48	,,	92·7
19·353		1			,,	,,	18447·4
05·169 Sa ?		1			,,	,,	18500·3
02·743		2			,,	,,	04·1
5354·855		1			1·46	5·1	18669·4
49·764 Nd?		1			,,	,,	87·3
49·283 Sa ?		1			,,	,,	89·0
43·719		1			,,	,,	18708·8
36·552		1			,,	,,	33·6
5295·153		1n			1·45	5·2	18880·0
18·825		1			1·43	,,	19156·2
12·873		1			1·42	,,	78·1
5163·780		<1			1·41	5·3	19360·4
56·590		<1			,,	,,	87·4

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
5153·592		< 1			1·41	5·3	19393·6
47·847		< 1			,,	,,	19420·3
43·853		< 1			,,	,,	35·4
36·639		2			,,	,,	62·7
15·986		1			1·40	5·4	19541·2
5087·657		1			1·39	,,	19650·0
68·033 La	W?	1			,,	,,	19726·1
43·451		1			1·38	,,	19822·2
37·819		1			,,	,,	44·5
37·532		2			,,	,,	45·6
4936·555		1			1·35	5·6	20251·4
26·153		1			,,	,,	94·2
21·397		1			,,	,,	20313·8
04·946		< 1			1·34	,,	82·0
4884·085		1			,,	,,	20469·1
52·298		1			1·33	5·7	20603·1
46·026		1			,,	,,	29·8
32·337		1			1·32	,,	88·2
25·571		1			,,	,,	20717·2
19·685		1			,,	,,	42·5
12·908		4			,,	,,	71·8
4781·100		2			1·31	5·8	20909·9
69·143		1			,,	,,	62·3
58·222		1			1·30	,,	21010·4
40·288		2			,,	,,	90·0
30·237		1			,,	,,	21134·8
23·018		1			1·29	,,	67·1
			4708·49	1	,,	,,	21232·4
01·404		1			,,	5·9	61·2
4692·036		1			1·28	,,	21306·7
85·398		1n	4685·37	1	,,	,,	37·1
84·980		1n			,,	,,	38·9
82·041		5 Ti ?	82·12	1	,,	,,	52·3
			75·76	2	,,	,,	81·0
			72·30	2	,,	,,	96·8
69·309 Nd?		1n			,,	,,	21410·5
			67·45	1n	,,	,,	19·1
			66·45	2	,,	,,	23·4
			64·05	2	,,	,,	34·7
61·253		1n			,,	,,	47·6
			49·13	2	1·27	,,	21503·5
33·112	4633·18	1n			,,	6·0	77·6
			30·32	2	,,	,,	89·8
19·689	19·66	3			,,	,,	21640·6
			16·39	1	1·26	,,	55·9
			06·99	5	,,	,,	21700·1
02·352		1			,,	,,	21·9
01·557		1n			,,	,,	25·8
			00·46	1	,,	,,	31·0
4583·267		1n			,,	,,	21812·5
			4581·86	2	,,	,,	19·2
80·886		1n			1·25	,,	23·8
			79·7	1n	,,	,,	29·5
			75·05	1	,,	,,	51·6
74·496	4574·48	5	74·52	1	,,	,,	54·3

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4573·484		1			1·25	6·0	21859·2
			4573·31	3	,,	,,	60·0
66·034	4566·02	4			,,	,,	94·9
			64·77	2	,,	6·1	21900·9
61·678		1			,,	,,	15·6
59·629		1			,,	,,	25·5
56·509	56·53	2			,,	,,	40·5
			54·28	1	,,	,,	51·3
			54·09	1	,,	,,	52·2
53·893	53·87n	1			,,	,,	53·2
52·115	52·13	4n			,,	,,	61·7
47·922		1			,,	,,	82·0
	47·33	1n			,,	,,	84·8
			47·00	3	,,	,,	86·4
30·966	30·98	5	31·00	1	1·24	,,	22064·2
			27·9	1b	,,	,,	79·2
27·692	27·68	2n			,,	,,	80·2
			24·3	1n	,,	,,	96·8
			23·61	3	,,	,,	22100·1
21·203	21·27	3n			,,	,,	11·7
11·613	11·66	2n			,,	,,	58·8
			11·25	2n	,,	,,	60·7
11·133	11·16	10			,,	,,	61·2
09·416	09·46	2n			,,	,,	69·7
			08·65	1n	,,	,,	73·5
			03·26	1	1·23	,,	22200·0
			00·0	1n	,,	,,	16·1
			4493·2	1b	,,	6·2	49·6
4473·683	4473·70	1n	72·75	1	,,	,,	22346·6
			71·50	1	,,	,,	57·7
			69·95	1	,,	,,	65·4
			64·42	1	1·22	,,	93·0
			64·30	1	,,	,,	93·7
			60·6	1b	,,	,,	22412·3
59·944	59·99	2n			,,	,,	15·5
			57·60	1	,,	,,	27·4
			57·00	1	,,	,,	30·4
50·890	50·95	1n			,,	,,	61·1
			47·31	3	,,	,,	79·3
			46·35	1n	,,	,,	84·0
41·905	41·93	3n			,,	,,	22506·6
41·214	41·22	3n			,,	,,	10·1
			37·38	2	,,	,,	29·6
33·159		1			1·21	6·3	51·0
30·611	30·61	1n			,,	,,	64·0
			29·62	1n	,,	,,	69·0
			27·5	1n	,,	,,	79·8
			26·87	1	,,	,,	83·0
25·256	25·16	1n			,,	,,	91·5
			20·82	1n	,,	,,	22614·0
19·729	19·73	2			,,	,,	19·5
			19·63	2	,,	,,	20·0
15·868	15·90	4	15·97	1	,,	,,	39·1
			11·72	1	,,	,,	60·6
			10·41	2	,,	,,	67·3

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4402·644 Nd	4402·70	4	4402·8	1b	1·21	6·3	22707·2
4398·606	4398·65	3			,,	,,	28·1
			4392·93	1	1·20	,,	57·5
			88·55	1	,,	,,	80·3
86·223	86·25	4	86·25	1n	,,	,,	92·3
			85·1	1n	,,	,,	98·2
78·965	78·99	3			,,	,,	22830·1
			78·14	1	,,	,,	34·4
75·289	75·30	2n			,,	,,	49·3
69·657 Nd	69·51	1			,,	,,	79·2
			68·64	2	,,	·4	84·0
			68·18	1	,,	,,	86·4
64·973	65·00	2n			,,	,,	22903·2
62·171		1n			,,	,,	17·9
60·965	61·01	2n			,,	,,	24·2
			60·1	1b	1·19	,,	28·8
55·257	55·27	1n			,,	,,	54·3
			51·80	2	,,	,,	72·6
			49·26	1	,,	,,	86·0
			48·88	1	,,	,,	88·0
			45·55	1n	,,	,,	23005·6
44·438 Ti ?	44·47	1n			,,	,,	11·5
			43·06	1	,,	,,	18·8
			31·57	2	,,	,,	79·9
29·745	29·80	1n			,,	,,	89·5
			27·56	1	,,	,,	23101·3
			26·50	2	,,	,,	07·0
22·897	22·93	1n			,,	,,	26·2
18·966	18·99	1n			1·18	,,	47·2
14·696	14·71	2n	12·63	1	,,	,,	70·2
			11·50	3	,,	,,	81·3
					,,	,,	87·4
03·116	03·10	1n	09·72	1	,,	,,	97·0
	01·25	1n Ti	01·17	4	,,	,,	23232·6
	00·70	1n Ti	00·72	1	,,	,,	45·5
			4299·76	4	,,	,,	50·7
			98·83	1	,,	,,	55·6
			96·34	1	,,	6·5	69·1
			95·80	1	,,	,,	72·1
			92·59	1	,,	,,	89·5
			92·23	1	,,	,,	89·4
			91·37	1	,,	,,	96·1
			89·55	3	,,	,,	23306·0
			87·15	2	,,	,,	19·0
4286·549	4286·55	2n	86·4	1b	,,	,,	22·3
			83·17	2	,,	,,	40·7
			80·76	1	1·17	,,	53·8
80·606	80·65	2			,,	,,	54·6
			79·65	1n	,,	,,	59·9
79·189	79·20	4			,,	,,	62·4
			77·66	1	,,	,,	70·8
			74·95	1n	,,	,,	85·6
			70·87	2	,,	,,	23417·9
			68·8	1n	,,	,,	19·3
68·380 Nd	68·43	2n			,,	,,	21·4

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			4266·18	2	1·17	6·5	23433·7
			62·22	3	,,	,,	54·4
			55·58	2	,,	,,	92·1
			54·81	1	,,	,,	96·3
			54·49	1	,,	,,	98·1
			53·11	1n	,,	6·6	23505·6
			49·60	1	,,	,,	25·0
			46·42	1	,,	,,	42·6
4245·445	4245·48	3n	45·43	1b	,,	,,	48·0
			42·8	1b	1·16	,,	62·7
			39·45	1n	,,	,,	81·4
			38·0	1n	,,	,,	90·0
			32·12	1	,,	,,	23622·2
			30·46	1	,,	,,	31·5
			29·98	2	,,	,,	34·2
			29·29	3	,,	,,	38·0
28·734	28·78	3n			,,	,,	41·0
			27·86	1	,,	,,	46·0
			18·09	3	,,	,,	23700·8
			14·90	2	,,	,,	18·8
			12·71	1	,,	,,	31·1
			12·20	1	,,	,,	34·0
			08·30	1	,,	,,	56·0
06·563	06·54	4			,,	,,	65·8
06·029	06·01	10	06·03	1	,,	,,	68·8
			05·46	5	1·15	,,	72·0
			01·67	2	,,	,,	93·5
			4199·02	1	,,	6·7	23808·4
			98·65	1	,,	,	10·5
			95·82	1	,,	,,	26·5
			95·25	4	,,	,,	29·8
			92·22	4	,,	,,	47·0
			91·05	6	,,	,,	59·7
			86·28	1	,,	,,	80·8
			84·60	2	,,	,,	90·4
			81·50	1	,,	,,	23907·2
4181·302 Sa	4181·36	4	81·32	1	,,	,,	08·2
81·042	81·05	1n			,,	,,	10·8
			79·99	1	,,	,,	16·8
	79·55	1b			,,	,,	19·3
78·062	78·08	4	78·04	1	,,	,,	27·8
	77·60	1			,,	,,	30·5
77·103	77·15	1	77·1	1n	,,	,,	33·2
75·344	75·40	3	75·3	1n	,,	,,	43·2
			74·48	1	,,	,,	48·4
			74·08	1	,,	,,	50·7
					,,	,,	63·0
	71·94	1	69·70	1	,,	,,	75·8
			68·28	8	1·14	,,	84·0
67·861	67·85	1n			,,	,,	86·4
			66·00	1	,,	,,	97·1
			64·80	8	,,	,,	24004·1
			63·82	8	,,	,,	09·7
			62·9	1b	,,	,,	15·0
			61·35	1n	,,	,,	24·0

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4160·100	4160·10	2n			1·14	6·7	24030·2
58·202	58·25	2n	4158·15	1	,,	,,	42·2
56·395	56·46	2n			,,	,,	52·4
			52·70	3	,,	,,	74·0
			52·20	1	,,	,,	76·9
50·891	50.93	2n			,,	,,	84·4
			50·26	4	,,	,,	88·2
			49·36	1	,,	,,	93·4
			48·89	1	,,	6·8	96·0
48·051	48·03	5	48·05	2	,,	,,	24100·9
			47·35	2	,,	,,	05·0
			46·68	1	,,	,,	08·9
			43·35	2	,,	,,	28·3
			42·42	1	,,	,,	33·7
			39·91	8	,,	,,	48·3
			39·56	3	,,	,,	50·4
			38·6	1b	,,	,,	56·0
			37·29	7	,,	,,	63·6
36·347	36·32	5	36·35	1	,,	,,	69·2
			35·6	1n	,,	,,	73·5
			34·77	2	,,	,,	78·3
			31·7	1b	,,	,,	96·3
			31·0	3b	,,	,,	24200·4
			30·10	4	1·13	,,	05·7
29·567	29·55	5	29·59	4	,,	,,	08·8
28·00	28·05	3r	28·2	2b	,,	,,	17·8
			27·1	1n	,,	,,	23·3
			26·4	1n	,,	,,	27·4
			25·75	1n	,,	,,	31·2
			25·45	1n	,,	,,	33·0
	24·97	1			,,	,,	35·8
			24·03	10	,,	,,	41·3
			22·98	1	,,	,,	47·5
			19·41	4	,,	,,	68·5
			17·05	3	,,	,,	82·4
			14·11	2	,,	,,	99·8
			12·32	1	,,	,,	24310·4
			11·03	1	,,	,,	18·0
			10·50	1	,,	,,	21·1
	10·05	1n			,,	,,	23·8
			06·36	1	,,	,,	45·7
05·166	05·17	4	05·21	1	,,	,,	52·3
04·341	04·39	2	04·40	2n	,,	,,	57·4
01·437		1			,,	,,	74·9
	01·06	2	01·12	10	,,	,,	77·0
			00·56	3	,,	,,	80·1
			4099·24	2	,,	6·9	87·9
			98·40	1	,,	,,	92·9
4097·325	4097·35	2			,,	,,	99·2
			96·17	1	,,	,,	24406·1
			95·76	1	,,	,,	08·6
			94·25	1b	,,	,,	17·6
			93·25	1b	1·12	,,	23·6
91·383	91·41	2n			,,	,,	34·7
			90·36	1	,,	,,	40·8

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
			4086·80	1	1·12	6·9	24462·1
4085·901	4089·95	1			,,	,,	67·5
			85·6	1n	,,	,,	69·3
			85·03	2	,,	,,	72·7
			84·35	1	,,	,,	77·8
			81·40	1	,,	,,	94·5
	79·89	3 Nb?	79·92	12	,,	,,	24503·5
79·358	79·31	2	79·4	1n	,,	,,	06·9
			77·23	1	,,	,,	19·6
76·039	{ 76·09 76·01	1 } 1			,,	,,	26·7
			73·28	1	,,	,,	43·3
	73·17	1n			,,	,,	44·0
			72·89	1	,,	,,	45·7
			71·15	1	,,	,,	56·2
			68·40	1	,,	,,	72·8
68·080	68·06	6n	68·06	1	,,	,,	74·8
67·418	67·36	3	67·35	2	,,	,,	79·0
			66·30	1	,,	,,	85·5
			64·98	1	,,	,,	93·5
64·739	64·76	5	64·76	1	,,	,,	94·8
			64·27	1	,,	,,	97·8
62·960	62·98	1			,,	,,	24605·6
			62·20″	2	,,	,,	10·3
61·528	61·53	5	61·57″	2	,,	,,	14·3
			60·96	2	,,	,,	17·8
			60·50	1	,,	,,	20·6
			59·85	1	,,	,,	24·5
			59·65	1	,,	,,	25·8
	59·10	2 Nb?	59·12	15	,,	,,	29·0
58·618	58·65	2n			,,	,,	31·9
	58·32	1n			,,	,,	33·8
			57·10	1	,,	,,	35·2
	55·53	1n	55·33	1n	,,	,,	51·4
	54·57	1	54·6	1n	1·11	,,	56·6
			51·68	1	,,	,,	74·2
			49·88	1	,,	7·0	85·1
			48·76	1n	,,	,,	91·9
			44·88	1	,,	,,	24715·6
			43·30	1n	,,	,,	25·3
			42·71	1	,,	,,	28·9
41·204	41·21	2n	41·1″	1	,,	,,	38·1
41·025	41·06	3n			,,	,,	39·1
			40·7″	1	,,	,,	41·2
39·748	39·77	1n	39·68	3r	,,	,,	47·2
			39·23	1	,,	,,	50·2
			37·8	1b	,,	,,	59·0
36·070	36·05	1n	36·05	1	,,	,,	69·7
			35·25	1	,,	,,	74·6
			33·36	2	,,	,,	86·2
			32·67	5	,,	,,	90·5
			31·5	1n	,,	,,	97·7
30·101	30·10	3	30·13	1	,,	,,	24806·2
			28·12	1	,,	,,	18·5
			27·46	1	,,	,,	22·6

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4027·091	4027·09	5	4027·10	1	1·11	7·0	24824·8
			26·51	1	,,	,,	28·4
			24·71	1	,,	,,	39·5
			23·40	1n	,,	,,	47·6
			23·30	1	,,	,,	48·2
			22·5	1n	,,	,,	53·2
			17·68	1	,,	,,	83·0
15·382	15·40	2n			1·10	,,	97·2
	13·48	1			,,	,,	24909·0
13·327	13·39	1n	13·41	2	,,	,,	09·7
12·298	12·26	1n	12·30	2n	,,	,,	16·4
			08·43	1	,,	,,	40·4
07·273	07·38	1			,,	,,	47·3
06·982	06·99	4	07·00	1	,,	,,	49·3
03·889	03·85	3			,,	,,	68·8
			01·3	1b	,,	7·1	85·
			00·77	2	,,	,,	88·1
3999·411	3999·44	4	3999·35	2	,,	,,	96·7
96·295	96·32	4	96·34	1	,,	,,	25015·9
	92·65	1n			,,	,,	38·9
			91·87	1	,,	,,	43·8
			91·3	1n	,,	,,	47·
	90·58	1			,,	,,	51·9
88·856	88·85	2	88·83	1	,,	,,	62·8
			88·30	1	,,	,,	66·2
84·011	84·02	1			,,	,,	93·2
82·054	82·11	3	82·15	1	,,	,,	25105·2
	81·19	1	81·17	1	,,	,,	11·1
			80·65	2	,,	,,	14·4
79·390	79·43	2n	79·50	1	,,	,,	22·1
			78·90	1	,,	,,	25·5
			78·09	1	,,	,,	30·6
			76·80	1	,,	,,	38·8
			76·67	1	,,	,,	39·6
			73·80	1	1·09	,,	57·7
			72·69	2	,,	,,	64·8
			72·04	2	,,	,,	68·9
			70·79	1	,,	,,	76·8
70·237	70·25	3	70·25	1	,,	,,	80·3
			66·40	5	,,	,,	25204·7
			65·85	3	,,	,,	08·2
	59·90	1			,,	,,	46·1
			59·48	1	,,	,,	48·7
			55·82	2n	,,	7·2	72·0
	54·47	1n			,,	,,	80·6
			53·20	1	,,	,,	88·8
			52·50	2	,,	,,	93·2
52·290	52·31	2			,,	,,	94·5
			49·60	2n	,,	,,	25311·8
	47·90	1			,,	,,	22·7
			47·67	1	,,	,,	24·2
			43·80	3	,,	,,	49·1
	42·40	1n			,,	,,	58·1
			41·41	2	,,	,,	64·4
			38·71	2n	,,	,,	81·8

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3937·951	3937·99	2n	3938·10	2	1·09	7·2	25386·3
			37·56	3	,,	,,	89·2
	36·70	1n	36·60	1	1·08	,,	95·1
			36·18	2n	,,	,,	98·1
			35·60	1	,,	,,	25401·9
			32·0	1n	,,	,,	25·
31·056	31·10	2			,,	,,	31·1
			30·00	1 Ti ?	,,	,,	38·1
			29·7	1n	,,	,,	40·
			29·44	1	,,	,,	41·7
	26·54	1	26·76	1	,,	,,	59·8
	25·41	1	25·38	1	,,	,,	67·9
			25·14	1	,,	,,	69·6
23·112	23·08	2n			,,	,,	82·9
22·919	22·94	2n			,,	,,	84·0
	22·60	1	22·55	2n	,,	,,	86·4
			20·95	1n	,,	,,	96·5
			19·85	2	,,	,,	25504·0
	19·61	1			,,	,,	05·5
			19·30	1	,,	,,	07·6
			19·18	1	,,	,,	08·3
18·638	18·66	3	18·76	1	,,	,,	11·6
			14·83	4	,,	,,	36·7
	13·62	1n	13·64	1 Ti	,,	,,	44·6
			13·16	1	,,	,,	47·6
	12·61	1			,,	,,	51·2
	12·30	1			,,	,,	53·2
					,,	,,	69·8
	09·50	1n	09·76	1	,,	,,	71·5
09·071		1	09·11	2	,,	7·3	74·1
	08·08	1n			,,	,,	80·7
			07·40	1	,,	,,	85·2
			05·77	10r	,,	,,	95·8
			04·33	1	,,	,,	25605·3
	04.06	1			,,	,,	07·0
	00·68	1	00·68	1 Ti	,,	,,	29·3
3898·902	3898·95	1			,,	,,	40·8
			3898·65	1	,,	,,	42·6
			98·41	2	,,	,,	44·2
			96·05	2	1·07	,,	59·7
			94·17	4	,,	,,	72·1
			93·86	3	,,	,,	74·1
	93·23	1n			,,	,,	78·3
			91·43	3	,,	,,	90·2
			90·49	1	,,	,,	96·4
			89·8	1b	,,	,,	25701·
			86·20	1	,,	,,	24·8
			85·82	4	,,	,,	27·3
85·697	85·65	1			,,	,,	28·3
			85·54	4	,,	,,	29·1
85·322	85·37	2n			,,	,,	30·4
			83·28	4	,,	,,	44·1
			79·50	3r	,,	,,	69·2
			79·05	2n	,,	,,	72·2
			77·67	3	,,	,,	81·4

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			3877·11	1	1·07	7·3	25785·1
			75·88	2	,,	,,	93·3
			75·55	1	,,	,,	95·6
3873·037		1			,,	,,	25812·2
			71·32	1n	,,	,,	23·7
			70·80	1n	,,	,,	27·1
			68·06	2	,,	,,	45·5
			66·4	1b	,,	,,	56·5
			65·17	2n	,,	,,	64·8
			64·50	1	,,	,,	69·3
			64·02	1	,,	,,	72·6
			63·52	2	,,	,,	75·8
			63·20	2n	,,	,,	78·0
			62·7	3b	,,	,,	81·
			59·09	3	,,	,,	25905·5
57·247		2	57·3	1n	,,	,,	14·2
					,,	,,	17·9
			56·1	2b	1·06	,,	26·
			55·60	2	,,	,,	29·0
			55·30	1	,,	,,	31·0
			54·9	1n	,,	,,	14·
			53·73	1	,,	,,	41·6
			53·53	1	,,	,,	42·9
			48·16	1	,,	,,	79·1
			46·02	2	,,	,,	93·6
			44·21	1	,,	,,	26005·8
			42·83	1	,,	,,	15·2
			41·95	1n	,,	,,	21·1
			39·17	1	,,	,,	40·0
			37·18	1	,,	,,	53·5
			36·87	1	,,	,,	55·6
			36·56	1	,,	,,	57·7
			36·08	1	,,	,,	61·0
			35·30	2	,,	,,	66·3
33·939	3833·90	3n	33·87	3	,,	,,	76·8
			32·00	6	,,	,,	88·7
			31·3	1n	,,	,,	93·5
			30·13	1	,,	,,	26101·3
			29·06	1	,,	,,	08·8
			28·37	2n	,,	,,	13·4
			27·15	1	,,	,,	21·8
			25·02	4	,,	,,	36·3
23·712					,,	,,	45·3
	21·95	12			,,	,,	57·4
20·878	20·99	2			,,	,,	64·3
			19·00	5	,,	,,	77·6
			15·64	3	1·05	7·4	26200·5
15·333		1n			,,	,,	02·6
			11·18	3	,,	,,	31·2
			10·65	4	,,	,,	34·9
			06·35	1	,,	,,	64·5
			04·90	4	,,	,,	74·5
			04·02	4	,,	,,	80·6
			03·10	5	,,	,,	86·9
			01·45	2	,,	,,	98·3

TANTALUM—*continued.*

Arc Spectrum: Wave-length: Rütten and Morsch	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}$−	Oscillation Frequency in Vacuo
			3801·30	2	1·05	7·4	26299·4
			01·17	1	,,	,,	26300·3
			3798·26	6	,,	,,	20·4
3797·535		1			,,	,,	25·5
			96·99	1	,,	,,	29·2
			96·72	1	,,	,,	31·1
			96·65	1n	,,	,,	31·6
			95·73	1n	,,	,,	38·0
94·546	3794·50	3n	94·62	1	,,	,,	46·1
92·142		2	92·17	1	,,	,,	62·8
			91·36	6	,,	,,	68·4
			89·63	1	,,	,,	80·4
88·474		1n			,,	,,	88·5
87·306	87·30	3C?	87·20	5	,,	,,	96·9
			86·38	1 Pb°?	,,	,,	26403·1
86·182 Ti ?		1			,,	,,	04·4
85·407	85·49	2			,,	,,	9·5
84·399	84·41	2	84·41	1	,,	,,	16·8
	84·02	2			,,	,,	19·5
83·909		3C?	84·00	1	,,	,,	20·0
			83·1	1n	,,	,,	26·
			82·57	4r	,,	,,	29·5
82·096					,,	,,	32·9
			81·17	4	,,	,,	39·4
	80·64	1			,,	,,	43·2
			79·7	1b	,,	,,	49·7
			79·33	1n	,,	,,	52·3
			77·8	1n	,,	,,	63·
			74·40	1n	,,	,,	65·8
			77·22	1n	,,	,,	67·1
			75·58	1	1·04	,,	78·6
			74·58	1	,,	,,	85·6
			73·30	1	,,	,,	94·6
			71·98	2	,,	7·5	26503·8
			70·87″	2n	,,	,,	11·6
	70·38	1			,,	,,	15·0
			70·12	1	,,	,,	16·9
			69·28	1	,,	,,	22·8
68·445	68·37	2			,,	,,	28·9
			66·27	2	,,	,,	44·0
			65·21	2	,,	,,	51·4
			64·26	1	,,	,,	59·1
			63·63	3	,,	,,	62·6
61·555	61·47	2	61·45	3 Ti	,,	,,	77·6
			61·3	1n	,,	,,	79·
			60·9	1b	,,	,,	82·
59·892C?		1	59·69	5	,,	,,	89·7
	59·41	2n			,,	,,	92·4
			55·88	2	,,	,,	26617·4
55·221	55·25	1			,,	,,	22·0
54·639		1	54·65	1	,,	,,	26·2
			53·30	2	,,	,,	35·7
	53·03 Ti	1	53·00	2	,,	,,	37·7
			51·77	1n	,,	,,	46·6
			51·4	1n	,,	,,	49·

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}-$	
			3750·75	1n	1·04	7·5	26653·8
3750·322	3750·35	1			,,	,,	56·8
50·003	50·00	1			,,	,,	59·2
			48·69	1	,,	,,	68·5
			44·15	2	,,	,,	26700·8
			42·56	5r	,,	,,	12·2
	41·21 Ti	1	41·18	2	,,	,,	21·9
			40·99	3	,,	,,	23·4
			40·90	3	,,	,,	24·0
			40·11	3	,,	,,	29·7
	39·93 Nb?	1	39·95	5	,,	,,	30·9
37·231		1n			,,	,,	50·3
	36·92	2	36·90	1	1·03	,,	52·5
			32·20	1	,,	,,	86·3
31·097	31·15	2			,,	,,	94·1
	29·95 Ti		29·97	1	,,	,,	26802·5
			27·39	1	,,	7·6	20·8
	26·37 Nb?	1	26·40	5	,,	,,	28·0
25·632		1	25·4	1n	,,	,,	33·5
24·939	24·95	1			,,	,,	38·4
			23·61	1	,,	,,	48·1
23·197	23·24	1			,,	,,	50·9
			21·72	1	,,	,,	61·6
	20·59	1	20·63	3	,,	,,	69·7
20·105 Fe ?					,,	,,	73·4
			17·68	1	,,	,,	90·9
			17·25	8	,,	,,	94·0
	14·00	1	13·95	3	,,	,,	26917·7
13·324					,,	,,	22·4
	13·17 Nb?	2	13·20	6r	,,	,,	23·4
			11·93	1	,,	,,	32·5
			11·49	2	,,	,,	35·7
			10·61	1	,,	,,	42·1
			06·35	1n	,,	,,	73·1
			04·29	1	,,	,,	88·1
			04·07	1	,,	,,	89·7
			03·34	1	,,	,,	95·0
	3698·00	1	3698·01	4	,,	,,	27034·0
			96·06	3	1·02	,,	48·2
3695·523	95·55	1n			,,	,,	52·1
94·685	94·65	2	94·8	1b	,,	,,	58·4
			93·55	1	,,	,,	67·6
93·181	93·20	2			,,	,,	69·3
92·799	92·80	1			,,	,,	72·1
			92·1	1b	,,	,,	77·
	91·55	1n	91·36	1	,,	,,	82·1
89·879	89·90	2			,,	,,	93·5
			89·20	1	,,	,,	98·5
			88·85	1	,,	,,	27101·1
			88·15″	5	,,	,,	06·3
87·608	87·63	1			,,	,,	10·2
86·979	86·96	1 Nd?			,,	,,	14·9
86·373	86·36	1			,,	,,	19·4
			83·69	8	,,	7·7	39·0
	83·25	1			,,	,,	42·2

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length: Rütten and Morsch	Wave-length: Exner and Haschek	Intensity and Character	Wave-length: Exner and Haschek	Intensity and Character	λ+	$\frac{1}{\lambda}$−	
			3681·85	1n	1·02	7·7	27152·6
3681·388	3681·42 81·23	1n 1n			,,	,,	56·1
			78·20	2	,,	,,	79·5
	77·05	1n	77·21	1	,,	,,	87·0
75·276	75·30	1			,,	,,	27201·0
74·969	74·98	1	74·91	2	,,	,,	03·4
			73·4	1b	,,	,,	15·
	71·85 Ti	1	71·7	1nPb?	,,	,,	26·5
			69·88	1	,,	,,	41·1
69·055		1	69·15	2	,,	,,	46·9
			68·77	1	,,	,,	49·4
	68·49	1n			,,	,,	51·5
	68·38	1			,,	,,	52·3
67·840	67·90	1			,,	,,	57·1
	67·22	1n	67·22	1	,,	,,	60·9
67·040	67·09	1n			,,	,,	62·1
	66·72	1n	66·70	1	,,	,,	64·7
			64·83	4	,,	,,	78·7
			63·80	1	,,	,,	86·4
62·489	62·47	2	62·48	1	,,	,,	96·2
			62·23	1	,,	,,	98·1
61·855	61·84	2	61·9	1n	,,	,,	27300·9
			60·51	3	,,	,,	10·9
			59·73	6	,,	,,	16·7
58·931	58·93	1n	58·9	1b	,,	,,	22·7
57·649	57·65	2			1·01	,,	32·2
57·454	57·42	1nSa?	57·3	1b	,,	,,	33·8
57·039	57·04	1			,,	,,	36·8
			56·09	1	,,	,,	43·9
53·908	53·98	1			,,	,,	60·0
53·540	53·58	1			,,	,,	62·9
52·559	52·56	1			,,	,,	70·4
			51·32	6	,,	,,	79·6
			50·93	1	,,	,,	82·6
			50·01	2	,,	,,	89·5
			45·07	1	,,	,,	27426·6
			43·5	1n	,,	,,	38·
	42·81 Ti	2	42·82	2	,,	,,	43·6
42·192	42·20	10	42·21	2	,,	,,	48·2
			40·78	1	,,	,,	59·0
			39·73	6 Pb?	,,	,,	66·9
			39·47	1	,,	,,	68·8
			39·17	1	,,	7·8	71·0
			38·91	1	,,	,,	73·0
			37·98	2	,,	,,	80·0
			37·70	1	,,	,,	82·1
			37·58	1n	,,	,,	83·0
	35·60 Ti	2	35·60	2	,,	,,	98·0
			34·60	2	,,	,,	27505·5
33·951	33·94	1n	33·85	1n	,,	,,	10·7
			33·46	2	,,	,,	14·2
			33·2	1b	,,	,,	16·
31·613 Fe?		1			,,	,,	28·2
			30·75	1	,,	,,	34·7

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
			3629·6	1n	1·01	7·8	27543·
3628·881	3628·85	1n	28·81	1	,,	,,	49·2
			28·30	1	,,	,,	53·3
27·188	27·20	1			,,	,,	61·7
26·757	26·78	9	26·73	3	,,	,,	65·0
			25·87	1	,,	,,	71·8
25·312	25·39	1	25·32	1	,,	,,	75·8
	24·25	1n			,,	,,	84·1
			21·16	1	,,	,,	27607·6
			19·83	4	,,	,,	17·8
	19·54	2	19·62	4	,,	,,	19·8
17·475	17·45	1	15·66	1	1·00	,,	35·9
			14·94	1	,,	,,	55·2
			13·60	1n	,,	,,	65·4
			13·22	1n	,,	,,	68·3
11·284	11·29	2			,,	,,	83·2
			10·8	1b	,,	,,	87·
	10·12	1n			,,	,,	92·1
09·485	09·30	1			,,	,,	97·7
09·011	08·90	2			,,	,,	27701·1
07·557	07·53	7	07·54	2	,,	,,	11·9
05·487 Cr?					,,	,,	27·7
	05·14	1			,,	,,	30·4
04·673		1n			,,	,,	34·0
02·659	02·63	1	02·70	3	,,	,,	49·4
	00·85	1n	01·34	1	,,	,,	61·6
			3599·78	1	,,	,,	71·7
			99·45	1	,,	,,	74·2
3597·014	3597·02	1n			,,	,,	93·0
95·795	95·79	3	95·79	1	,,	,,	27802·5
			94·13	3	,,	7·9	15·3
93·644 Cr?	93·88 93·48	1n 1n	93·67	1	,,	,,	18·9
	93·10	1n			,,	,,	23·2
92·638	92·67	1n			,,	,,	26·7
	92·32	1n			,,	,,	29·3
92·038	92·05	1n			,,	,,	31·4
91·665					,,	,,	34·3
91·504 Fe?		1n	91·40	1	,,	,,	35·2
90·522	90·50 Cy?	3			,,	,,	43·3
			89·50	3	,,	,,	51·1
			89·23	3	,,	,,	53·2
			88·15	1n	,,	,,	61·6
86·435	86·46	2			,,	,,	67·1
			85·11	2	,,	,,	85·2
			84·67	1	,,	,,	88·7
	84·38	2	84·37	1	,,	,,	90·9
84·078 C?		1			,,	,,	93·3
			82·52	1	,,	,,	27905·4
81·987*	82·00	1			,,	,,	09·5
80·391	80·42 Nb?	2	80·45	6	,,	,,	21·8
79·233	79·21	2	79·10	1n	,,	,,	31·4
		1	78·82	1	,,	,,	34·3

* 3581·994 La, 81·991 Sa, 81·979 Nd.

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		1	3577·86	1	0·99	7·9	27941·8
			77·00	1	,,	,,	48·5
			76·00	5	,,	,,	56·3
3574·482 Nd?		1			,,	,,	68·2
73·574	3573·59	3			,,	,,	75·2
			73·10	1n	,,	,,	79·0
			72·96	1n Pb ?	,,	,,	80·1
			72·63	1	,,	,,	82·7
72·004	72·01	2			,,	,,	87·6
71·389 Fe?		1			,,	,,	92·4
70·259 Fe?		1			,,	,,	28001·3
			69·64	1	,,	,,	06·1
			68·89	1	,,	,,	12·0
			68·65	1	,,	,,	13·9
			68·20	1	,,	,,	17·4
66·873	66·89	4	66·88	1	,,	,,	27·8
			65·78	2n	,,	,,	36·4
			63·76	2	,,	,,	52·3
			63·64	2	,,	,,	53·3
			59·74	2	,,	,,	84·0
58·034	58·08	2n			,,	,,	97·1
			56·77	1	,,	,,	28107·5
	55·85	1			,,	,,	14·8
			54·81	8	,,	,,	23·0
54·494	54·50	1n	54·69	1	,,	,,	25·5
53·576	53·57	1n			,,	,,	32·8
			52·14	1	,,	,,	44·1
			51·31	1n	,,	8·0	50·6
			50·63	2	,,	,,	56·0
			49·45	1	,,	,,	65·4
49·207	49·16	2	49·24	1	,,	,,	67·3
		2	48·28	1	,,	,,	74·7
			47·87	1	,,	,,	77·9
			44·81	3	,,	,,	28202·3
			44·17	3	,,	,,	07·4
			43·15	1	,,	,,	15·5
			42·75	1n	,,	,,	18·5
42·054	42·02	2	42·03	1	,,	,,	24·4
40·965	40·93	2n	41·11	4	,,	,,	32·6
			39·78	1	,,	,,	42·3
			37·78	3	0·98	,,	58·3
37·649	37·60	1	37·60	4	,,	,,	59·6
	36·43	2			,,	,,	69·1
35·808		1n			,,	,,	74·1
35·514	35·50	2n	35·47	6	,,	,,	76·6
34·704	34·66	1			,,	,,	83·1
			34·35	2n	,,	,,	85·7
			33·83	1	,,	,,	89·9
32·353	32·33	1			,,	,,	28301·8
31·735	31·72	3	31·77	1	,,	,,	06·6
			29·03	1	,,	,,	28·4
28·739	28·71	2	28·65	1n	,,	,,	31·1
27·212	27·20	2	27·23	1	,,	,,	43·0
23·399	23·30	1n	23·30	1	,,	,,	74·2
			20·82	1n	,,	,,	94·5

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}-$	
3520·595	3520·60	1n	3520·66	1	0·98	8·0	28396·1
20·274		1	20·21	1	,,	,,	99·1
19·971		1	19·73	1	,,	,,	28402·3
	17·60	1n	17·82	3	,,	,,	19·6
			17·20	1	,,	,,	23·7
			17·02	1	,,	,,	25·2
15·580	15·57	1	15·59	4	,,	,,	37·0
13·764	13·76	2			,,	,,	51·5
11·174	11·20	8	11·20	1	,,	,,	72·3
			10·47	5	,,	8·1	78·1
			08·09	2	,,	,,	97·4
	07·03	1			,,	,,	28506·0
05·312	05·32	2	05·28	1	,,	,,	20·2
05·105	05·10	3			,,	,,	21·8
04·011	04·00	3	04·05	1	,,	,,	30·5
			03·35	1n	,,	,,	36·1
03·018	03·02	2	03·05	1	,,	,,	38·6
02·648	02·65	2			,,	,,	41·7
02·124	02·13	1			,,	,,	46·0
			00·10	1n	,,	,,	62·5
			3498·79	2	0·97	,,	73·2
3498·003	3497·98	5			,,	,,	79·7
			97·2	1b	,,	,,	86·1
			96·37	2	,,	,,	93·0
93·841 Fe?	93·60	1n			,,	,,	28614·7
91·069	91·10	2	91·18	2	,,	,,	36·0
90·717	90·76	1			,,	,,	39·1
			89·23	2	,,	,,	51·5
88·996	88·99	1	88·96	2	,,	,,	53·6
87·533*	87·53	1			,,	,,	65·5
86·825	86·83	1			,,	,,	71·2
	86·17	1			,,	,,	76·7
84·767	84·77	1	84·80	1n	,,	,,	88·1
			84·25	2	,,	,,	92·5
			83·16	1n	,,	,,	28701·5
			81·3	1n	,,	,,	17·
80·640	80·67	5	80·69	2	,,	,,	22·0
			80·40	1	,,	,,	24·2
79·580	79·59	1	79·75″	4	,,	,,	30·3
			78·90	3	,,	,,	36·6
77·586	77·58	2	77·60	1	,,	,,	47·4
77·356	77·35	2	77·38	1 Ti	,,	,,	49·4
	74·45	1n	74·4	1b	,,	,,	73·4
74·034	74·05	1	74·1	1b	,,	,,	76·7
73·464	73·48	1			,,	,,	81·5
72·976	73·00	1	73·20	1	,,	,,	84·6
72·680	72·67	2			,,	,,	88·2
			71·3	1b	,,	,,	99·6
			70·47	1n	,,	8·2	28806·3
			69·59	1	,,	,,	13·6
	67·03	1			,,	,,	34·9
	65·50	1n			,,	,,	47·7
63·912	63·94	4	63·94	2	,,	,,	60·8

* 3487·548 Yb, 87·547 Sa.

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			3463·20	1	0·97	8·2	28866·8
	3463·04	1n			,,	,,	68·2
			62·75	1n	,,	,,	70·6
			59·88	1n	,,	..	94·5
	58·65	1			0·96	..	28904·8
			56·6	1n	..	..	22·
			55·03	2	..	..	35·1
			54·85	1	,,	..	36·6
	53·52	1n			,,	,,	47·8
3453·041	53·11	1			..	..	51·2
			52·47	1	,,	.,	56·6
			51·8	1n	,,	..	62·
			50·89	1	..	..	69·8
50·528	50·53	1			..	..	72·9
49·046	49·03	1			..	..	85·5
			48·83	1n	..	..	87·1
			48·36	1	..	..	91·1
47·429	47·42	1			..	,,	99·0
47·004	47·04 46·95	1n	47·01	1	..	..	29002·5
46·051	46·03	1			..	..	10·6
	45·82	1			..	..	12·5
45·662	45·65	1			..	,,	13·8
45·220	45·22	1			..	..	17·5
44·820	44·81	1			,,	,,	20·9
			44·45	1	..	,,	24·0
44·199	44·21	1			..	,,	26·1
			42·9	1n	..	..	37·
40·746					..	,,	55·3
40·385	40·38	1			,,	,,	58·3
			40·06	1	,,	,,	61·1
39·180			39·1	1n	..	,,	68·5
38·538	38·63 38·44	1n 1	38·55	1	,,	,,	73·9
			38·37	1	,,	,,	75·3
	37·50	1			,,	,,	82·7
	37·20	1			,,	,,	85·2
			37·05	1n	,,	,,	86·5
36·138	36·13	3	36·16	1n	,,	,,	94·2
34·639	34·64	2			,,	,,	29106·9
	32·77	1n	32·87	5	,,	8·3	22·3
31·054	31·08	3	31·07	2	,,	,,	37·1
	29·46	1			,,	,,	50·8
			29·17	1	,,	,,	53·3
			27·57	1	,,	,,	66·9
26·855	26·88	2			,,	,,	72·9
			26·71	4	,,	,,	74·2
26·337					..	,,	77·4
			25·98	1	,,	,,	80·4
			25·59	4	,,	,,	83·7
24·578	24·55	2			,,	,,	92·5
			23·88	1	,,	,,	98·3
			22·95	1n	,,	,,	29206·3
	21·95	1			,,	,,	14·8
			20·86	1	,,	,,	24·1

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3419·856	3419·84	2			0·96	8·3	29232·8
19·677	19·64	2n			,,	,,	34·4
18·382	18·44	1			,,	,,	45·1
17·153	17·15	2			,,	,,	55·8
			3416·13	1n	0·95	,,	64·7
15·996	15·99	1			,,	,,	65·7
15·392	15·39	1	15·40	1	,,	,,	70·9
14·259	14·26″	2	14·25	1	,,	,,	80·6
	13·77	1			,,	,,	84·8
13·032	13·03	2	13·07	3	,,	,,	91·1
11·842	11·84	1			,,	,,	29301·4
			09·34	2	,,	,,	22·9
			08·82	3	,,	,,	27·4
			08·52	1	,,	,,	30·0
07·069	07·09	4	07·09	1	,,	,,	42·3
06·810	06·79	2	06·81	1	,,	,,	44·7
			06·30	1	,,	,,	49·1
			05·56	1	,,	,,	55·4
	04·31	1			,,	,,	66·2
	03·11	1	03·15	1n	,,	,,	76·4
	01·98	1			,,	,,	86·3
			3399·9	1n	,,	,,	29404·
3398·449	3398·43	3	98·45	1	,,	,,	16·9
97·556	97·55	1			,,	,,	24·6
			96·55	1n	,,	8·4	33·2
			96·05	1	,,	,,	37·6
			95·13	1	,,	,,	45·5
	94·76	1	94·77	1	,,	,,	48·7
			92·47	2	,,	,,	68·6
			92·11	2	,,	,,	71·8
88·952	88·95	1	89·0	1n	,,	,,	99·2
88·464	88·46	1	88·45	1n	,,	,,	29503·5
	87·96	1 Ti	87·95	1	,,	,,	07·9
87·561	87·59	1			,,	,,	11·2
87·367	87·36	1	86·39	2	,,	,,	13·0
85·176	85·20	3	85·18	1	,,	,,	32·1
83·975	83·92	2			,,	,,	42·9
			83·03	1	,,	,,	50·9
82·068	82·11	1			,,	,,	59·1
			81·05	1	,,	,,	68·2
80·745	80·78	1			,,	,,	70·7
			80·55	1	,,	,,	73·0
	80·44	1 Ti			,,	,,	73·5
			80·20	1	,,	,,	75·6
79·641	79·65	3	79·61	1	,,	,,	80·6
			79·47	1	,,	,,	82·0
	78·30	1n			,,	,,	92·3
	77·88	1n			0·94	,,	96·0
76·614	76·61	2			,,	,,	29607·1
76·180	76·17	3	76·20	1	,,	,,	10·8
			75·03	1	,,	,,	20·0
			74·37	1n	,,	,,	26·8
74·064	74·15				,,	,,	29·1
	72·95		72·8	1n	,,	,,	39·2
71·663	71·66	5	71·65	1	,,	,,	50·6

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			3371·48	1	0·94	8·4	29652·2
3369·972	3369·99	1			,,	,,	65·4
69·408	69·40	2			,,	,,	70·4
			69·30	2b	,,	,,	71·4
68·869	68·87	1			,,	,,	75·1
68·570	68·55	1n	68·50	1n	,,	,,	78·0
	67·64				,,	,,	86·0
			67·07	1	,,	,,	91·0
66·811	66·79	1			,,	,,	93·4
			65·71	1	,,	,,	29703·0
65·154	65·15				,,	,,	07·9
	63·74				,,	,,	20·4
62·646	62·65	2			,,	,,	30·1
61·769	61·78	3			,,	,,	37·8
			61·07	1n	,,	8·5	43·9
59·101	59·11	2			,,	,,	61·3
58·651	58·62	4	58·52	3	,,	,,	65·8
56·752	56·75	2			,,	,,	82·2
56·154	56·15	1			,,	,,	87·5
55·718	55·71	1			,,	,,	91·4
			54·83	2	,,	,,	99·3
52·631	52·66	1			,,	,,	29818·8
51·637	51·66	3			,,	,,	27·6
51·104	51·11	2	49·51	4	,,	,,	{ 32·4 46·6
			48·40	1	,,	,,	56·5
	47·19	1			,,	,,	67·3
			47·01	1	,,	,,	68·9
			46·88	1	,,	,,	70·1
45·233	45·24	1			,,	,,	84·7
			44·10	2	,,	,,	94·9
	43·85	1	43·83	2	,,	,,	97·2
43·597	43·60				,,	,,	99·4
	43·53				,,	,,	29900·0
	42·02	2 Ti	42·10	3	,,	,,	13·2
			41·74	2	,,	,,	16·0
			40·6	1n	,,	,,	26·
40·035	40·02	3	40·05	1	,,	,,	31·3
38·612	38·60	2			0·93	,,	44·1
37·908	37·93	2			,,	,,	50·3
			35·35	1	,,	,,	73·4
	33·24	1			,,	,,	92·3
32·933	32·95	1			,,	,,	95·0
32·792	32·84	1	32·8	1b	,,	,,	96·1
32·537	32·55	2	32·3	1n Mg ?	,,	,,	98·6
31·138	31·12	3	31·16	2	,,	,,	30011·3
	29·03	1			,,	,,	30·3
	28·42	1n			,,	,,	35·8
28·065	28·06	1			,,	,,	39·0
27·560			26·76	1	,,	,,	45·5
25·865	25·87	1			,,	,,	50·8
			24·8	1n	,,	8·6	68·
			24·1	1n	,,	,,	75·
			22·12	1	,,	,,	92·7
			20·98	1	,,	,,	30103·0

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			3319·75	1	0·93	8·6	30114·1
	3319·61	1n			,,	,,	15·4
3319·559					,,	,,	15·9
			19·38	1	,,	,,	17·5
			19·10	1	,,	,,	20·0
18·968	18·99	5	18·97	1	,,	,,	21·2
18·662	18·66	2			,,	,,	24·0
18·036	18·04	5	18·10	1	,,	,,	29·5
			15·37	1	,,	,,	53·9
			12·75	1	,,	,,	77·8
11·259	11·30	9	11·28	2	,,	,,	91·3
09·905	09·94	2			,,	,,	30203·6
			08·19	1	,,	,,	20·2
	07·23	1			,,	,,	26·2
			06·50	1	,,	,,	34·9
			05·78	1	,,	,,	41·4
	05·48	1			,,	,,	44·2
	05·27	1			,,	,,	46·1
			04·97	1n	,,	,,	48·9
04·499	04·54	2			,,	,,	53·0
04·163	04·20	2			,,	,,	56·0
			03·50	1n	,,	,,	62·3
02·892	02·91	1			,,	,,	67·8
02·023	02·05	1	01·7	1n	,,	,,	78·8
3299·892	3299·91	2	3299·8	1b	0·92	,,	95·3
	99·41	1			,,	,,	99·8
			96·16	1	,,	,,	30329·7
95·451	95·49	3			,,	,,	36·1
	94·87	1n			,,	,,	41·6
			94·55	1	,,	,,	44·6
94·058	94·09	2			,,	,,	49·7
92·627	92·64	2			,,	,,	62·2
			92·20	2	,,	,,	66·2
92·069	92·04	1			,,	,,	67·6
			91·17	1	,,	,,	75·7
	90·00	1n			,,	,,	86·5
			88·02	1	,,	,,	30404·8
	87·42	1n			,,	8·7	10·3
	85·81	1n	85·80	1	,,	,,	25·2
	85·26	1n			,,	,,	30·3
	84·75	1			,,	,,	35·0
			83·63	3	,,	,,	45·4
80·991	80·99	2	80·95	1	,,	,,	70·0
			80·82	1	,,	,,	71·5
			80·1	1b	,,	,,	78·0
79·404	79·36	2	79·38	1	,,	,,	84·9
			77·80	1	,,	,,	99·6
	77·32	1			,,	,,	30504·0
76·013	76·02	1n			,,	,,	16·2
75·802	75·76	2	75·78	1	,,	,,	18·4
75·041	75·02	3	75·02	1	,,	,,	25·4
74·487	74·57	1			,,	,,	29·6
73·252	73·25	2	73·22	1	,,	,,	42·0
			72·37	1n	,,	,,	50·2
	71·26	1n			,,	,,	54·3

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3269·283	3269·26	1			0·92	8·7	30579·1
	67·00	1			,,	,,	30600·4
65·736	65·68	1			,,	,,	12·5
65·462	65·50	1			,,	,,	14·7
			3264·77	1	,,	,,	21·3
64·209	64·25	1			,,	,,	26·4
63·889	63·91	2			,,	,,	29·5
			63·51	3	,,	,,	33·2
	63·14	1n			,,	,,	36·6
			60·73	3	,,	,,	59·3
60·332	60·34	2	60·3	1n	,,	,,	63·0
60·001	60·02	2			,,	,,	66·0
59·761	59·76	2			0·91	,,	69·4
58·333	58·36	2			,,	,,	81·7
	57·98	1			,,	,,	85·2
56·863	56·90	1			,,	,,	95·5
			54·98	1n	,,	,,	30713·4
			54·20	3	,,	,,	20·8
53·258	53·29	1			,,	,,	29·5
	53·08	1			,,	,,	31·4
			51·78	1	,,	8·8	43·6
	51·47	1	51·5	1n	,,	,,	46·2
51·398					,,	,,	47·2
50·493	50·52	2			,,	,,	55·6
			49·68	1	,,	,,	63·5
48·638	48·65	2	49·10	1	,,	,,	69·0
			47·69	2 Cu ?	,,	,,	73·3
	47·05	1			,,	,,	82·3
45·510	45·41	1			,,	,,	88·4
	43·50	1			,,	,,	30803·5
42·955	42·98	3			,,	,,	22·1
42·176	42·19	3	42·15	1 Ti	,,	,,	27·2
41·059	41·09	3	41·12	1	,,	,,	34·6
					,,	,,	45·0
40·098	40·13	2			,,	,,	54·3
			38·2	1n	,,	,,	72·5
37·980	37·99	2	37·87	1n	,,	,,	74·9
	36·71	2 Ti	36·51	2	,,	,,	87·7
34·806	34·81	2	34·65	2 Ti	,,	,,	30904·9
	32·41	1			,,	,,	27·9
	31·80	1n			,,	,,	33·7
30·996	31·01	3			,,	,,	41·3
30·020	29·95	2			,,	,,	50·1
			29·70	1	,,	,,	53·8
29·344	29·34	2	29·36	1	,,	,,	57·2
27·444	27·44	2			,,	,,	75·5
26·979	27·00	2n			,,	,,	79·8
	26·45	1			,,	,,	85·0
			25·62	5	,,	,,	93·0
23·954	23·98	4	23·97	1	,,	,,	31008·9
			23·50	1	,,	,,	13·4
21·442	21·46	2			,,	,,	33·1
	20·20	1n			0·90	,,	45·2
19·701	19·73	1			,,	,,	49·8
17·048					,,	,,	75·6

TANTALUM—*continued.*

Arc Spectrum: Wave-length, Rütten and Morsch	Arc Spectrum: Wave-length, Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length, Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ +	Reduction to Vacuum: $\frac{1}{\lambda}$ −	Oscillation Frequency in Vacuo
3217·041	3217·04	3	3217·1	1b	0·90	8·8	31075·7
	16·27	1			,,	8·9	83·0
	16·09	1			,,	,,	84·8
			15·72	3	,,	,,	88·3
	14·00	3			,,	,,	31105·0
	09·97	1			,,	,,	44·0
08·721	08·74	1			,,	,,	56·1
	08·30	1			,,	,,	60·3
07·970	07·95	2			,,	,,	63·5
06·500	06·49	2	06·50	3	,,	,,	77·8
05·095	05·10	2	05·14	1	,,	,,	91·2
	03·86				,,	,,	31203·4
			03·50	2	,,	,,	07·0
02·085	02·08	1			,,	,,	20·8
00·582	00·59	1			,,	,,	35·5
3198·777	3198·79	3			,,	,,	43·2
96·494	96·50	1			,,	,,	75·3
95·390	95·40	1			,,	,,	86·1
	95·09	1	3195·11	4	,,	,,	89·0
	95·00	1			,,	,,	90·0
			94·50	1	,,	,,	94·9
92·369	92·35	2			,,	,,	31315·9
			91·59	2	,,	,,	23·4
91·265	91·29	2	91·25	2	,,	,,	26·6
89·814	89·80	1			,,	,,	40·8
			89·45	1	,,	,,	44·5
	88·55	1			,,	,,	53·3
			87·57	1	,,	,,	62·9
84·656	84·66	3			,,	,,	91·6
			84·36	1	,,	,,	94·6
82·688	82·70	2			,,	,,	31411·0
81·810	81·82	2			,,	9·0	19·6
81·068	81·08	4	81·02	1	0·89	,,	27·1
			80·42	3	,,	,,	33·4
79·609	79·65	1	79·6	1n Ca	,,	,,	41·2
78·373 }	78·31″	2			,,	,,	54·0
78·278 }					,,	,,	54·6
78·042	78·04	1			,,	,,	56·9
76·410	76·40	3			,,	,,	73·1
			75·97	1	,,	,,	77·4
73·700	73·69	4			,,	,,	31500·0
			73·35	1	,,	,,	03·4
72·980	73·00	2			,,	,,	07·0
70·404	70·40	4			,,	,,	32·7
68·365	68·36	1			,,	,,	53·1
68·276	68·30	1			,,	,,	53·8
67·641	67·65	2			,,	,,	60·2
	66·83	1n			,,	,,	68·6
66·541	66·51	1			,,	,,	71·4
63·948	63·95	2			,,	,,	97·1
63·648	63·64	1			,,	,,	31600·1
	63·55	1	63·50	4	,,	,,	01·3
63·232	63·22	2			,,	,,	04·3
62·835	62·85	2			,,	,,	08·1
	62·76	1			,,	,,	08·9

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3161·548	3161·55	1			0·89	9 0	31621·1
59·141	59·16	1	3159·0	1b	,,	,,	45·1
58·042	58·06	2			,,	,,	56·1
57·769	57·77	1			,,	,,	58·9
56·883	56·85	2			,,	,,	68·0
	55·60	1			,,	,,	80·7
55·361	55·36	2			,,	,,	83·1
54·572	54·60	1			,,	,,	90·9
	54·05	1n			,,	,,	96·3
	53·25	1n			,,	,,	31704·3
	52·64	1n			,,	,,	10·4
	52·10	1n	52·2	1b	,,	,,	15·9
50·967	50·98	1			,,	,,	27·2
48·142	48·14	2			,,	,,	55·8
47·482	47·49	2			,,	,,	62·4
	46·87	1n			,,	9·1	68·5
			45·52	2	,,	,,	82·1
43·042	43·06	2			,,	,,	31807·1
	41·53	1			0·88	,,	22·5
38·588	38·60	1			,,	,,	52·3
37·538	37·56	1			,,	,,	62·9
35·999	35·99	2			,,	,,	78·7
34·009	34·03	1			,,	,,	98·8
33·672	33·68	1			,,	,,	31902·3
32·756	32·77	3			,,	,,	11·6
	31·36	1n			,,	,,	25·9
	30·90	1n	30·90	3	,,	,,	30·6
30·682	30·70	3			,,	,,	32·7
30·391	30·43	1			,,	,,	35·6
30·053	30·09	2			,,	,,	39·1
29·654	29·68	2			,,	,,	43·2
29·226	29·25	1			,,	,,	47·5
27·859	27·90	3			,,	,,	61·4
			27·6	2n	,,	,,	64·3
25·073	25·10	3			,,	,,	90·0
21·001	21·06	1			,,	,,	32031·3
19·692	19·70	1			,,	,,	45·3
17·545	17·52	2			,,	,,	67·5
15·972	15·95	2			,,	,,	83·7
13·996	14·00	2			,,	9·2	32103·8
	10·93	1n			,,	,,	35·5
	10·22	1n			,,	,,	42·9
	07·89	1n			,,	,,	67·0
07·311	07·32	2			,,	,,	72·9
04·519	04·54	1			,,	,,	32201·8
03·353	03·37	4			,,	,,	13·9
01·817	01·84	1			,,	,,	29·8
01·110	01·15	2n			0·87	,,	37·1
3095·498	3095·50	3			,,	,,	95·8
	94·28	1n	3094·30	3	,,	,,	32308·4
93·965	93·98	3			,,	,,	11·7
	93·10	1	93·0	1b	,,	,,	21·2
92·546	92·54	3			,,	,,	26·6
92·151	92·19	1			,,	,,	30·5
	88·11	2 Ti	88·0	1b	,,	,,	73·1

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3087·855	3087·85	2			0·87	9·2	32375·8
87·624	87·61	2			,,	,,	78·2
85·630	85·64	2			,,	,,	99·0
82·543	82·57	1			,,	9·3	32431·3
			3082·3	1b Al ?	,,	,,	34·0
81·950	81·95	2			,,	,,	37·7
80·088	80·08	2			,,	,,	57·3
	79·67	1			,,	,,	61·7
	79·40	1			,,	,,	64·6
78·335	78·34	2			,,	,,	75·8
77·334	77·33	3			,,	,,	86·4
			76·96	1	,,	,,	90·3
76·483	76·50	1			,,	,,	95·3
75·429	75·39	1			,,	,,	32506·7
73·495	73·52	1			,,	,,	26·8
	73·11	1			,,	,,	31·0
73·451	72·48	1			,,	,,	37·9
	70·66	1			,,	,,	57·0
			69·9	1b	,,	,,	65·0
69·342	69·32	4			,,	,,	71·1
66·876	66·87	1			,,	,,	97·2
			64·7	1b	,,	,,	32620·3
63·988	64·00	1	64·0	1b	,,	,,	27·8
63·667	63·69	3			,,	,,	31·2
	63·24	1n			0·86	,,	35·9
60·385	60·40	3			,,	,,	66·2
58·748	58·76	2			,,	,,	83·7
	57·36	1			,,	,,	98·7
57·206	57·27	1n			,,	,,	32700·0
56·715	56·73	1			,,	,,	05·5
			55·7	1b	,,	,,	16·4
54·914	54·93	1			,,	,,	24·8
52·026	52·02	1			,,	9·4	55·8
50·204	50·20	2			,,	,,	75·3
49·661	49·63	4			,,	,,	81·3
48·970	48·92	3			,,	,,	88·8
48·384	48·35	1n			,,	,,	95·0
46·058	46·05	2			,,	,,	32820·0
			44·87	1n	,,	,,	32·7
44·033	44·01	1			,,	,,	41·9
	42·56	1n			,,	,,	57·6
42·147	42·16	3			,,	,,	62·1
41·095	41·06	1			,,	,,	73·7
40·858	40·80	1			,,	,,	76·4
40·570	40·57	1			,,	,,	79·2
			39·9	1n	,,	,,	86·4
37·647 }	37·58	2			,,	,,	32910·8
37·507 }					,,	,,	12·3
36·401	36·36	1			,,	,,	24·5
			32·88	1	,,	,,	62·6
30·401	30·38	1			,,	,,	89·6
29·648	29·65	1			,,	,,	97·7
28·895	28·87	2			,,	,,	33006·1
			28·51	1	,,	,,	10·1
27·608	27·61	3			,,	,,	20·0

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
3025·280	3025·26	2			0·86	9·5	33045·4
			3024·85	In	,,	,,	50·0
24·388	24·36	1			,,	,,	55·2
	24·21	1			,,	,,	57·0
			22·90	In	,,	,,	71·3
	22·40	1			0·85	,,	76·8
21·187		1			,,	,,	90·1
20·761		1			,,	,,	94·7
20·619		1			,,	,,	96·3
19·779	19·76	1			,,	,,	33105·6
16·473	16·49	1			,,	,,	41·7
12·653	12·62	5	12·65	In	,,	,,	84·0
11·989	12·00	4			,,	,,	91·1
11·230	11·21	3			,,	,,	99·6
10·952	10·92	2			,,	,,	33202·8
06·680	06·63	1			,,	,,	50·0
	05·10	In			,,	,,	67·3
05·024	05·04	1			,,	,,	68·0
04·246	04·26	1			,,	,,	76·6
	02·10	1			,,	,,	33300·5
01·657	01·65	1			,,	,,	05·5
	01·25	1			,,	,,	10·0
01·060					,,	,,	12·1
	2999·48	1	2994·90	1	,,	,,	30·2
2994·559					,,	9·6	82·4
91·358	91·34	1			,,	,,	33420·1
			90·45	2	,,	,,	30·2
89·612	89·56	2			,,	,,	39·8
89·164	89·15	1			,,	,,	44·6
88·694	88·65	2			,,	,,	50·1
86·928	86·89	2			,,	,,	69·8
	86·52	1			,,	,,	74·2
86·165					,,	,,	78·2
84·469	84·45	1			,,	,,	97·3
81·325	81·32	1			0·84	,,	33532·6
			80·86	1	,,	,,	37·8
			80·02	1	,,	,,	47·2
			79·10	1	,,	,,	56·6
78·871	78·85	2			,,	,,	60·3
78·305	78·27	1			,,	,,	66·7
			77·77	1	,,	,,	72·6
76·896	76·86	1			,,	,,	82·6
76·382	76·31	1			,,	,,	88·6
	76·21	1			,,	,,	90·2
75·678	75·66	2			,,	,,	96·3
	74·67	1			,,	,,	33607·6
			74·23	2	,,	,,	12·5
73·358					,,	,,	22·4
			72·20	2	,,	,,	35·5
70·026	70·00	1			,,	9·7	60·3
69·582	69·58	2			,,	,,	65·2
	68·40	In			,,	,,	78·4
66·041	66·03	2			,,	,,	33705·3
65·669	65·66	3			,,	,,	09·6
65·284	65·26	4			,,	,,	14·0

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2964·033	2964·04	1			0·84	9·7	33728·1
63·440	63·43	3			,,	,,	34·9
63·190	63·19	1			,,	,,	37·7
57·994	58·00	1			,,	,,	96·9
57·720	57·72	2			,,	,,	33801·1
56·974	57·00	1n	2956·98	1	,,	,,	08·5
55·583	55·56	1			,,	,,	24·7
54·060		1			,,	,,	42·0
53·683	53·65	3			,,	,,	46·5
53·120	53·10	2			,,	,,	52·9
52·034	52·05	3			,,	,,	65·2
		1	51·01	3	,,	,,	77·0
47·028	47·01	2	47·00	1	,,	,,	33923·0
			46·0	1b	,,	,,	34·6
	45·80	1			,,	,,	36·9
	43·89	1			,,	9·8	58·9
42·249	42·25	2			0·83	,,	77·8
41·656	41·68	1n	41·61	3	,,	,,	84·7
[illegible]	41·48	1			,,	,,	86·7
40·326	40·31	3			,,	,,	34000·1
40·223	40·20	2			,,	,,	01·3
39·384	39·36	2			,,	,,	11·1
38·541	38·56	1			,,	,,	20·6
34·960	34·95	1			,,	,,	62·3
33·666	33·67	3			,,	,,	77·2
32·798	32·79	2			,,	,,	87·4
			31·55	1	,,	,,	34101·8
	31·10	1			,,	,,	07·1
			27·91	3	,,	,,	44·2
26·569	26·55	1			,,	,,	60·0
25·769	25·75	1			,,	,,	69·3
25·334	25·32	3			,,	,,	74·4
	22·97	1n			,,	,,	34202·0
19·098	19·06	1	19·07	1	,,	9·9	47·5
17·217	17·21	1	17·18	1	,,	,,	69·2
15·605	15·57	2			,,	,,	88·5
15·449	15·44	2			,,	,,	90·2
	15·06	1			,,	,,	94·7
14·240	14·22	2			,,	,,	34304·5
13·560	13·56	1n			,,	,,	12·5
	13·45	1n			,,	,,	13·8
			11·88	2	,,	,,	32·2
			10·71	2	,,	,,	46·0
09·024	09·02	2	09·05	1n	,,	,,	65·8
			08·39	2	,,	,,	73·4
05·354	05·35	2	05·40	1	,,	,,	34409·3
04·193	04·20	2			0·82	,,	23·0
02·131	02·17	3			,,	,,	47·3
01·159	01·18	1			,,	,,	58·9
00·858	00·88	1n			,,	,,	62·5
00·473	00·48	2			,,	,,	69·2
2899·154	2899·16	2	2899·39	2	,,	,,	81·9
98·512	98·54	1			,,	,,	90·4
			97·94	2	,,	,,	97·4
95·209	95·22	1			,,	10·0	34529·8

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
2894·275	2894·28	1			0·82	10·0	34549·9
	92·07	1n			,,	,,	67·3
91·954	91·95	3			,,	,,	68·7
91·148	91·15	1			,,	,,	78·3
90·414	90·40	1	2890·47	1n	,,	,,	86·9
89·485	89·48	1			,,	,,	98·3
			88·96	1	,,	,,	34604·5
85·526	85·52	1			,,	,,	45·8
			83·31	3	,,	,,	72·4
82·444	82·45	1			,,	,,	82·7
			81·9	4b	,,	,,	89·3
81·343	81·34	1			,,	,,	96·1
			80·89	1	,,	,,	34701·5
80·123	80·12	2			,,	,,	10·8
79·847	79·85	1			,,	,,	14·0
	79·60	1	79·5	1b	,,	,,	17·0
	79·18	1n			,,	,,	22·1
	79·06	1n			,,	,,	23·6
77·795	77·77	1	77·8	1b	,,	,,	39·0
			77·14	3	,,	,,	46·7
76·224	76·20	1			,,	,,	58·0
			75·52	3	,,	,,	66·3
75·023					,,	,,	72·3
74·652	74·60	1n			,,	,,	77·1
74·277	74·26	2			,,	,,	81·6
73·666	73·67	2			,,	,,	88·8
73·466	73·47	2			,,	,,	91·1
72·929					,,	,,	97·7
71·522	71·51	2			,,	10·1	34814·7
68·759	68·74	2	68·66	3	,,	,,	48·8
	67·48	1n	67·55	1n	,,	,,	63·5
	66·26	1n			,,	,,	78·6
	65·44		65·8	1n	,,	,,	88·6
64·609	64·60	1n			,,	,,	98·7
62·116	62·10	2			,,	,,	34929·2
61·223	61·22	2	61·23	2n	0·81	,,	40·0
60·999	61·01	1			,,	,,	42·7
58·542	58·54	2	58·57	1n	,,	,,	72·7
57·386	57·37	1			,,	,,	87·0
	56·81	1			,,	,,	94·0
	52·46	1	52·49	1n	,,	,,	35047·2
			52·2	1n Mg?	,,	,,	62·9
51·090	51·09	3			,,	,,	64·3
50·597	50·59	3			,,	,,	70·3
49·935	49·90	1			,,	,,	78·6
			49·7	1n	,,	,,	81·3
48·630	48·58	2	48·4	1b	,,	,,	94·8
48·159 Ky	48·14	1			,,	10·2	35100·3
46·934 Ky	46·85	1			,,	,,	15·8
			46·36	2	,,	,,	22·4
			45·95	1n	,,	,,	27·4
45·457	45·44	2n			,,	,,	33·6
44·859	44·85	1			,,	,,	41·0
44·561	44·55	2	44·55	2	,,	,,	44·7
44·347	44·34	2			,,	,,	47·3

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
2842·914	2842·91	2	2842·73	2	0·81	10·2	35165·8
			41·25	2	,,	,,	85·6
40·526	40·50	1	40·5	1n	,,	,,	94·7
	38·36	1	38·3	1b	,,	,,	35221·4
38·051	38·04	1			,,	,,	25·3
			35·20	1	,,	,,	60·7
34·515	34·50	1			,,	,,	69·3
33·744	33·74	2	33·3	1b	,,	,,	78·8
32·807	32·81	1			,,	,,	90·5
	29·90	1			,,	,,	35326·7
28·679	28·68	2	28·63	1	,,	,,	42·2
	27·70	1d	27·6	1n	,,	,,	54·2
27·272	27·26	1			,,	,,	59·6
					,,	,,	61·1
26·339	26·29	1	27·15	1	,,	,,	71·6
24·945	24·92	1			0·80	,,	89·0
22·155	22·19	1			,,	10·3	35423·2
19·464	19·46	1			,,	,,	57·5
17·818	17·59				,,	,,	81·0
17·195	17·17	2	17·16	2	,,	,,	85·9
			16·80	1	,,	,,	91·0
15·214	15·20	1			,,	,,	35511·1
15·097	15·13	1			,,	,,	12·3
14·900	14·90	1			,,	,,	14·9
	14·40	1	14·42	1n	,,	,,	21·1
			11·83	1	,,	,,	53·7
11·015	11·03	1	10·99	1	,,	,,	64·1
06·677	06·68	2			,,	,,	35619·0
06·403	06·40	2			,,	,,	22·4
04·950		1			,,	,,	41·0
			03·9	1n	,,	,,	54·
			02·82	3 Mg ?	,,	,,	68·1
02·166	02·17	2	02·1	1n Pb ?	,,	,,	76·3
10·259					,,	,,	88·0
00·691	00·66	1			,,	,,	95·4
2798·493	2798·50	1			,,	10·4	35723·1
97·858	97·87	3			,,	,,	31·2
96·658	96·66	1			,,	,,	46·5
96·435	96·45	2			,,	,,	49·3
			95·65	4 Mg ?	,,	,,	59·5
	93·98	1	94·02	1	,,	,,	80·4
95·008		← 1			,,	,,	67·6
			93·15	1	,,	,,	91·5
92·081		← 1			,,	,,	35805·2
			91·90	1	,,	,,	07·5
91·763	91·80	1			,,	,,	08·9
91·475	91·49	2	91·49	1	,,	,,	12·8
90·806	90·83	1			,,	,,	21·4
89·838					,,	,,	34·0
88·388	88·40	1			,,	,,	52·5
87·789	87·79	2			,,	,,	60·3
	86·89	1			,,	,,	71·9
85·073	85·06	2	85·06	1	0·79	,,	95·4
81·448	81·49	1			,,	,,	35941·8
	80·46	1	80·37	2	,,	,,	54·9

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2779·180	2779·20	1			0·79	10·4	35971·3
75·968	75·99	2			,,	,,	36012·9
75·475	75·46	1			,,	10·5	19·5
75·222	75·22	1	2875·20	1	,,	,,	22·8
			71·9	1n	,,	,,	25·7
74·984	75·00	1	71·50	1	,,	,,	65·8
	68·17	1n	68·24	2	,,	,,	71·0
			66·05	1n	,,	,,	14·0
					,,	,,	36142·7
			65·43	1n	,,	,,	50·2
			63·75	1n	,,	,,	72·5
	63·46	2	63·50	1	,,	,,	75·8
61·769	61·78	3			,,	,,	98·1
	59·16	1	59·1	1n	,,	,,	36231·4
			58·9	1n	,,	,,	35·8
58·403	58·40	2	58·45	1n	,,	,,	42·2
			54·67	1	,,	,,	91·5
			53·17	2n	,,	,,	36311·3
52·598	52·60	3	52·59	1	,,	,,	18·8
52·410	52·40	1			,,	,,	21·2
	50·42	1n	50·5	1n	,,	10·6	47·5
49·946	49·90	2	49·93	1	,,	,,	54·0
48·883	48·85	2	48·89	1	,,	,,	67·9
47·366	47·22	1			,,	,,	89·1
46·778	46·87	1n			,,	,,	95·1
	46·76	1			,,	,,	95·9
			2745·85	1	,,	,,	36408·0
			45·40	1n	,,	,,	14·0
			45·07	1n	,,	,,	18·3
43·695	43·65	1			,,	,,	36·9
42·508		1			,,	,,	52·4
41·270	41·25	1			0·78	,,	69·0
			40·31	1	,,	,,	81·6
39·368	39·35	2	39·34	1	,,	,,	94·4
37·429					,,	,,	36520·0
36·350	36·32	1			,,	,,	34·6
	35·34	1	35·34	1	,,	,,	47·9
			33·37	1r	,,	,,	74·3
33·094	33·00	1n			,,	,,	78·6
32·079	32·15	1n			,,	,,	91·1
			30·45	1	,,	,,	36613·4
27·872	27·85	2			,,	,,	48·1
27·549	27·51	3			,,	,,	52·6
	25·52	1n	25·55	1	,,	10·7	79·3
			23·98	1n	,,	,,	36700·3
			23·77	1n	,,	,,	03·1
			22·12	2	,,	,,	25·4
21·916	21·91	1			,,	,,	28·2
20·984			21·03	1n	,,	,,	40·6
20·844	20·84	2			,,	,,	42·7
			20·4	1b	,,	,,	48·6
			20·0	1b	,,	,,	54·0
19·119			19·12	1	,,	,,	65·9
18·478	18·45	1			,,	,,	74·8
			17·74	1	,,	,,	84·6

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			2717·43	1n	0·78	10·7	36788·8
2717·269	2717·25	2			,,	,,	91·1
			16·75	2	,,	,,	98·0
			16·00	1	,,	,,	36808·1
			15·45	1	,,	,,	15·6
14·756	14·75	3	14·80	1	,,	,,	24·8
			10·88	1	,,	,,	77·7
10·213	10·22	2	10·28	1	,,	,,	86·4
09·363	09·36	2	09·38	2	,,	,,	98·3
			07·99	1	,,	,,	36917·1
06·773	06·78	2			,,	,,	33·6
			06·58	1	,,	,,	36·3
04·396	04·40	1	04·44	1	,,	,,	65·9
03·141	03·16	1			,,	10·8	83·1
	02·89	1	02·8	1n	,,	,,	86·6
			02·64	1	,,	,,	90·1
			02·31	1	,,	,,	94·6
			00·28	1	,,	,,	37022·4
			2699·00	1	0·77	,,	40·0
2698·376	2698·37	2	98·4	1n	,,	,,	48·6
			97·21	3	,,	,,	64·5
96·890	96·90	1			,,	,,	68·9
	95·85	1	95·7	1b	,,	,,	83·2
	95·60	2			,,	,,	86·7
94·836					,,	,,	97·2
94·603			94·63	2	,,	,,	37100·3
93·434	93·46	1			,,	,,	16·3
92·475	92·49	2			,,	,,	29·6
			91·89	1	,,	,,	37·8
91·376	91·40	2			,,	,,	44·7
	89·35	1	89·38	1	,,	,,	72·7
			86·50	1	,,	,,	37212·3
85·235	85·24	4	85·25	3	,,	,,	29·8
84·343	84·37	2	84·40	1	,,	,,	41·9
81·949	81·99	1			,,	,,	75·2
80·726	80·79	2	80·75	1	,,	,,	92·1
80·130	80·17	2	80·17	1	,,	,,	37300·5
			78·8″	1n	,,	10·9	19·2
			77·80	1	,,	,,	33·2
75·954	75·99	3	75·99	3	,,	,,	58·6
			73·70	2	,,	,,	90·4
	72·61	1	72·61	1 Mn?	,,	,,	37405·7
			72·04	2	,,	,,	13·7
71·696	71·75	1			,,	,,	18·1
			71·40	1	,,	,,	22·7
	69·70	1	69·65	1	,,	,,	46·8
68·675	68·72	2	68·69	1	,,	,,	60·6
68·130	68·18	1			,,	,,	68·2
			67·86	1	,,	,,	72·3
			67·40	1	,,	,,	78·8
			67·20	1n	,,	,,	81·6
	65·70	2	65·68	1	,,	,,	37503·8
			65·34	1	,,	,,	07·8
			64·31	1	,,	,,	22·3
			·68	1	,,	,,	30·1

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			2663·20	1n	0·77	10·9	37537·9
2662·164	2662·18	1			,,	,,	52·4
61·932	61·99	1			,,	,,	55·4
61·402	61·45	2	61·42	1	,,	,,	61·0
	59·51	1	59·48	1	,,	,,	90·2
	58·96	1	58·93	1	,,	,,	98·0
			58·16	1	,,	,,	37609·1
57·300	57·40	1			,,	,,	20·6
56·651	56·69	3	56·65	1	,,	,,	30·3
			56·16	2	,,	,,	37·4
			54·50	1	0·76	11·0	60·9
53·356	53·36	3	53·35	1	,,	,,	77·0
	51·34	2	51·27	2	,,	,,	37706·3
47·560	47·56	3	47·55	1	,,	,,	59·7
46·862	46·88	1n			,,	,,	69·5
46·439	46·45	1			,,	,,	75·5
46·280	46·32	1	46·34	1	,,	,,	77·3
	45·20	1	45·17	1	,,	,,	93·5
	44·67	1n	44·65	1	,,	,,	37801·0
43·941	43·97	1			,,	,,	11·1
			42·32	2	,,	,,	34·5
			41·13	1	,,	,,	51·6
	38·76	1	38·70	1n	,,	,,	86·0
			38·20	1n	,,	,,	93·6
			38·05	1n	,,	,,	95·8
36·965	36·99	2	36·98	1	,,	,,	37911·2
36·742	36·75	2			,,	,,	14·5
36·131	36·02	1			,,	,,	24·2
35·650	35·66	3	35·64	3	,,	,,	30·3
			33·86	1	,,	,,	56·1
33·595		1	33·25	1b	,,	,,	59·9
			32·62	1	,,	,,	74·0
			32·37	1	,,	,,	77·6
	30·63	1n	30·65	1	,,	11·1	38002·5
			28·9	1b	,,	,,	27·6
			27·51	1	,,	,,	47·7
	25·56	1			,,	,,	76·0
24·180	24·23	1			,,	,,	95·7
			23·08	1	,,	,,	38112·0
			20·53	1	,,	,,	49·1
15·745	15·77	1			,,	,,	38218·8
15·564	15·56	1			,,	,,	21·6
	15·38	1			,,	,,	24·3
			14·2	1b	,,	,,	41·5
	12·74	1	12·72	1	,,	,,	63·0
11·426	11·46	1			,,	,,	81·9
09·092	09·10	1	09·08	1	0·75	11·2	38316·3
08·711	08·71	2	08·72	1	,,	,,	21·9
08·258	08·33	1n			,,	,,	28·0
	07·95	1	07·93	1	,,	,,	33·4
			06·55	1	,,	,,	53·7
			06·26	1	,,	,,	58·0
			05·19	1	,,	,,	73·7
			04·90	1	,,	,,	78·0
			04·65	1	,,	,,	81·7

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
	2603·95	1			0·75	11·2	38392·0
2603·585	03·60	2	2603·57	2	,,	,,	97·4
			03·06	1	,,	,,	38405·1
02·476	02·49	1	01·40	1	,,	,,	14·2
01·150	01·16	1	01·13	1	,,	,,	33·4
	00·84	1	00·82	1	,,	,,	38·1
00·210	00·25	1	00·26	1	,,	,,	46·8
2599·478		2			,,	,,	58·1
			2599·0	1b	,,	,,	65·1
96·718					,,	,,	99·0
	2596·55	2	96·55	2	,,	,,	38501·4
	96·23	1	96·26	1	,,	,,	06·0
	95·68	2	95·67	1	,,	,,	14·4
95·337	95·36	2	95·37	1	,,	,,	19·2
			94·82	1	,,	,,	27·1
	94·35	2	94·35	1	,,	,,	34·1
93·645	93·80	2 Mn	93·78	2	,,	,,	43·1
93·172	93·20	2			,,	,,	51·4
			92·66	1	,,	,,	59·2
			92·23	1n	,,	,,	65·6
			91·05	2	,,	,,	83·5
	89·89	1	89·90	1	,,	,,	38600·4
			88·97	1n	,,	,,	14·2
	85·99	1n			,,	11·3	58·6
	85·75	1n			,,	,,	62·3
84·810	84·82	1			,,	,,	76·2
	84·61	1	84·58	1	,,	,,	79·5
	84·15	1	84·10	3	,,	,,	86·5
			81·65	1n	,,	,,	38725·1
			80·68	1	,,	,,	38·2
80·262	80·27	1			,,	,,	44·4
79·713	79·75	1			,,	,,	52·4
			79·12	1	,,	,,	61·6
			78·30	1	,,	,,	74·0
77·876	77·90	1			,,	,,	80·1
77·456	77·46	2	77·42	2	,,	,,	86·8
			76·52	1	,,	,,	38800·7
			76·13	1	,,	,,	06·0
75·598	75·57	1			,,	,,	14·8
			74·94	1	,,	,,	24·5
74·511	74·50	1			,,	,,	31·1
73·882	73·91	1			,,	,,	40·3
73·637	73·66	1			,,	,,	44·0
			73·23	1	,,	,,	50·3
71·562	71·61	1	71·51	1	,,	,,	75·6
			71·41	1	,,	,,	77·9
	69·24	1	69·20	1	,,	,,	38911·0
			68·10	1	,,	11·4	27·9
			65·51	1	,,	,,	67·4
			64·90	1	0·74	,,	76·5
	63·82	1			,,	,,	82·9
	62·20	1			,,	,,	39017·6
60·865	60·77	1	60·72	1	,,	,,	39·1
			59·96	1	,,	,,	51·7
59·256	59·54	1	59·49	1	,,	,,	58·4

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
			2558·40	1	0·74	11·4	39075·5
			58·0	1n	,,	,,	81·6
	2557·80	1	57·75	1	,,	,,	85·1
			57·00	1	,,	,,	96·9
	56·60	1	56·56	1	,,	,,	39103·3
			55·70	1	,,	,,	16·8
	55·13	1			,,	,,	25·5
	55·01	1	54·95	1n	,,	,,	27·8
	54·73	2	54·67	2	,,	,,	32·1
			53·58	1	,,	,,	49·3
			53·20	1	,,	,,	55·1
	51·84	1	51·79	1	,,	,,	76·4
			51·46	1	,,	,,	81·8
2551·281	51·27	1			,,	,,	84·7
	51·20	1			,,	,,	85·8
49·471	49·46	1			,,	,,	39212·5
	46·86	1			,,	11·5	52·5
			45·77	1	,,	,,	69·3
	45·56	1	45·62	1	,,	,,	72·1
			44·96	2	,,	,,	81·8
			44·53	1	,,	,,	88·5
			44·06	1	,,	,,	95·8
			42·49	1	,,	,,	39320·0
			41·56	1	,,	,,	34·4
	38·03	1	38·05	1	,,	,,	89·0
			34·15	1	,,	,,	39448·5
	32·23	1	32·24	2	,,	,,	79·3
			31·39	1	,,	,,	92·5
			31·06	1	,,	,,	97·6
			28·69	2n r	,,	11·6	39534·6
			28·02	1	,,	,,	45·0
			27·51	1	,,	,,	53·0
26·557	26·56	1			,,	,,	67·9
	26·49	1			,,	,,	69·0
	26·14	1			,,	,,	74·5
			24·30	3n	,,	,,	39603·3
			21·52	1	,,	,,	47·0
			19·40	2	,,	,,	80·4
			18·18	1	,,	,,	99·6
			16·12 Ti ?	3n r	0·73	,,	39732·1
			14·5	2b r	,,	,,	57·7
			13·98	1	,,	,,	66·0
	13·23	1n	13·19	1	,,	,,	78·1
	12·76	1	12·6	1n	,,	,,	85·3
			11·08	1	,,	11·7	39811·8
			10·75	1	,,	,,	17·0
07·585	07·55	1			,,	,,	67·6
			07·02	2n r	,,	,,	76·3
			05·36	1	,,	,,	39902·7
04·557	04·45	1			,,	,,	16·4
			03·07	1	,,	,,	39·2
	02·09	1	02·05	1	,,	,,	55·2
			01·5	1b	,,	,,	64·3
			2499·80	1	,,	,,	91·5
			98·37	1	,,	,,	40014·4

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		λ +	1/λ −	
	2492·27	1	2492·22	1	0·73	11·8	40112·7
			92·12	1	,,	,,	14·7
	90·58	1	90·34	1	,,	,,	41·4
	88·78	2	88·74	2	,,	,,	68·8
			88·23	1n	,,	,,	77·4
			87·69	1	,,	,,	86·1
	85·03	1	84·98	1	,,	,,	40229·6
			83·9	1n	,,	,,	47·5
			83·35	1n	,,	,,	56·4
			81·91	1	,,	,,	79·7
			80·00	1	,,	,,	40310·8
			78·33	1	,,	,,	38·0
			77·42	1	,,	,,	52·8
	76·76	1	76·71	1	,,	11·9	63·8
			75·36	1	,,	,,	86·2
	74·71	1			,,	,,	96·9
	73·20	1	73·17	1	,,	,,	40421·8
			73·0	1n	,,	,,	25·
	71·01	2			,,	,,	57·4
			70·95	2	,,	,,	58·3
			69·43	1	0·72	,,	83·3
			68·45	1	,,	,,	99·3
	67·45	1n	67·41	1	,,	,,	40516·1
	67·09	1	63·85	1	,,	,,	75·0
			62·1	1n	,,	,,	03·8
			61·08	1n	,,	,,	20·7
			60·03	1	,,	12·0	37·9
			58·17	1	,,	,,	68·1
			57·55	2n r	,,	,,	78·9
			54·70	1n	,,	,,	40726·2
			53·97	1n	,,	,,	38·3
			51·90	1	,,	,,	72·7
			50·4	1n	,,	,,	97·7
			49·50	1	,,	,,	40812·7
			44·7	2n	,,	,,	92·8
	44·20	1n	44·19	1	,,	,,	40901·3
			43·90	1	,,	12·1	06·1
			43·45	1	,,	,,	13·6
			42·74	1	,,	,,	25·5
			42·22	1	,,	,,	34·2
			41·90	1	,,	,,	39·6
			41·40	1	,,	,,	48·0
			40·10	1	,,	,,	69·8
			39·87	1	,,	,,	75·7
			38·73	1n	,,	,,	92·8
			38·23	1	,,	,,	41001·2
			37·80	1n	,,	,,	08·5
			37·48	1n	,,	,,	13·9
			36·56	1	,,	,,	29·4
			36·00	1	,,	,,	38·8
			35·2	2b	,,	,,	52·3
			33·86	1	,,	,,	74·9
	33·65	1n	33·63	1	,,	,,	78·6
	32·75	2	32·75	2 r	,,	,,	93·6
			31·11	1	,,	,,	41121·4

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave Length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			2430·3	1n	0·72	12·1	41135·1
	2429·74	1	29·75	1	,,	,,	44·5
			29·52	1	,,	,,	48·3
			28·08	1	,,	12·2	72·6
	27·70	1			,,	,,	79·0
			26·92	1n	,,	,,	92·3
			25·98	1	,,	,,	41208·2
			23·55	1	,,	,,	49·6
			21·96	2	0·71	,,	76·7
			18·78	2	,,	,,	41350·9
	17·94	1			,,	,,	45·3
			17·40	1	,,	,,	54·6
	16·99	1	17·02	2n	,,	,,	61·3
			16·27	1	,,	,,	73·9
	15·28	1	15·30	1	,,	,,	90·7
			14·58	1n	,,	,,	41402·9
			14·01	1n	,,	,,	12·6
			12·56	1	,,	12·3	37·4
			08·33	1	,,	,,	41510·3
			05·97	1	,,	,,	51·0
			05·44	1	,,	,,	60·1
			03·77	1	,,	,,	89·0
	02·23	1	02·22	1	,,	,,	41614·6
	00·71	2	00·70	3	,,	,,	42·1
			00·02	1	,,	,,	54·0
			2398·58	1	,,	,,	79·0
			89·62	1	,,	12·4	41835·3
			89·18	1	,,	,,	42·6
			88·4	1b	,,	,,	56·6
			87·59	1	,,	,,	70·8
	2387·17	1	87·16	3	,,	,,	78·3
			84·43	1	,,	,,	41926·3
			83·82	1	,,	,,	37·1
	81·63	1n	81·66	2	,,	12·5	75·3
	81·26	1n	81·24	2	,,	,,	82·2
			78·40	1n	,,	,,	42032·6
			76·49	2	,,	,,	66·4
			74·03	1n	0·70	,,	42110·0
			72·86	1n	,,	,,	30·7
			71·12	1	,,	,,	61·7
			70·88	1	,,	,,	65·9
			70·05	1n	,,	,,	80·7
			69·40	1	,,	,,	92·3
			67·33	1n	,,	12·6	42222·1
			65·29	1	,,	,,	65·6
	64·34	1	64·35	2	,,	,,	82·4
			57·02	1	,,	,,	42414·2
			56·15	1	,,	,,	29·5
			55·67	1	,,	,,	38·2
			54·10	1	,,	12·7	66·4
			53·92	1	,,	,,	69·6
			52·98	1	,,	,,	86·6
			52·48	1	,,	,,	95·6
			52·07	1	,,	,,	42503·0
			49·33	1n	,,	,,	52·6

TANTALUM—*continued.*

Arc Spectrum: Wave-length: Rütten and Morsch	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ +	Reduction to Vacuum: $\frac{1}{\lambda}$ −	Oscillation Frequency in Vacuo
			2347·09	1	0·70	12·7	42593·2
			46·60	1n	,,	,,	42602·1
			46·15	1n	,,	,,	10·3
			43·7	1n	,,	,,	54·9
			42·62	1	,,	,,	74·5
			41·73	1	,,	,,	90·8
			41·02	1	,,	12·8	42703·6
			40·13	1	,,	,,	19·9
			38·73	1	,,	,,	45·4
			38·3	1n	,,	,,	42853·3
			35·83	1	,,	,,	98·5
			34·97	1	,,	,,	42914·3
			34·22	1	,,	,,	28·1
	2332·30	1	32·22	1	,,	12·9	64·7
	32·14	1	32·10	2	,,	,,	66·9
			24·35	1	0·69	,,	91·4
			24·22	1	,,	,,	43012·3
			24·07	1	,,	,,	15·1
			19·20	1	,,	,,	43105·4
			16·16	1n	,,	,,	62·0
			15·54	1	,,	,,	73·6
			14·98	1	,,	,,	84·0
			13·40	2	,,	13·0	43213·4
			12·73	1	,,	,,	25·9
			11·30	1	,,	,,	52·7
			09·35	1	,,	,,	89·2
			08·61	1	,,	,,	43313·7
			04·88	1n	,,	,,	73·2
			03·58	1	,,	,,	97·7
			03·00	1	,,	,,	43408·6
			02·32	1	,,	,,	31·4
			02·20	1	,,	,,	23·7
			01·57	1	,,	,,	35·6
			00·92	1	,,	13·1	47·8
			00·42	1	,,	,,	57·2
			2299·06	1	,,	,,	82·9
			98·20	1	,,	,,	99·2
			96·90	2	,,	,,	43523·8
			95·80	2	,,	,,	44·7
			92·65	1	,,	,,	43604·5
			92·28	1	,,	,,	11·6
			90·49	1	,,	,,	45·7
			89·25	1	,,	,,	69·3
			87·36	1	,,	13·2	43705·3
			85·35	1	,,	,,	43·8
			85·10	1n	,,	,,	48·6
			84·48	1n	,,	,,	60·4
			83·25	1n	,,	,,	84·0
			83·10	1	,,	,,	86·9
			82·26	1	,,	,,	43803·0
			81·61	1	,,	,,	15·5
			80·60	1n	,,	,,	34·9
			75·74	1	0·68	13·3	43928·4
			75·28	1n	,,	,,	37·3
			74·25	1n	,,	,,	57·3

TANTALUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave Length		Intensity and Character	Wave-length	Intensity and Character			
Rütten and Morsch	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			2273·73	1n	0·68	13·3	43967·3
			72·70	1	,,	,,	87·2
			71·95	1	,,	,,	44001·7
			71·03	1n	,,	,,	19·6
			70·28	1	,,	,,	34·1
			69·67	1	,,	,,	46·0
			69·30	1	,,	,,	53·1
			65·67	1n	,,	,,	44123·7
			62·39	2	,,	13·4	87·6
			61·70	1n	,,	,,	44201·1
			61·50	1	,,	,,	05·0
			60·65	1	,,	,,	21·6
			59·65	1	,,	,,	41·2
			58·78	1	,,	,,	58·3
			56·57	1	,,	,,	44301·6
			55·8	1n	,,	,,	16·8
			52·31	1	,,	,,	85·5
			50·85	1	,,	13·5	44414·2
			49·81	1	,,	,,	34·7
			48·49	1	,,	,,	60·8
			43·90	1	,,	,,	44551·8
			42·7	1n	,,	,,	75·6
			39·51	1	,,	,,	44639·1
			39·02	1	,,	,,	48·9
			37·5	1n	,,	13·6	79·1
			37·3	1n	,,	,,	83·1
			27·90	1	0·67	,,	44871·7
			26·57	1	,,	13·7	98·4
			23·40	1	,,	,,	44962·5
			18·12	1	,,	,,	45069·5
			17·89	1	,,	,,	74·2
			16·71	1	,,	,,	98·2
			15·63	1	,,	,,	45120·2
			14·5	1b	,,	13·8	43·1
			12·50	1	,,	,,	83·9
			11·9	1n	,,	,,	96·2
			11·00	1	,,	,,	45214·6
			10·2	1n	,,	,,	31·0
			08·02	1	,,	,,	75·6
			07·17	1	,,	,,	93·1
			03·7	1b	,,	13·9	45364·3
			2199·7	1n	,,	,,	45446·8
			96·10	1n	,,	,,	45521·4
			93·96	1	,,	,,	65·8
			93·31	1	,,	,,	79·3
			82·75	1	,,	14·0	45799·8

Zirconium.

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Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
4934·236		1					1·35	5·6	20261·0
				4851·7		2	1·33	5·7	20606·
				38·8		3	1·32	,,	60·
				28·1		2	,,	,,	20706·
				25·3		2	,,	,,	18·
				15·8		8	,,	,,	59·
				10·3		2	,,	,,	83·
4806·047		1		06·0		2	,,	,,	20801·4
4788·853		1		4789·1		2	1·31	,,	76·1
85·094		1		84·7		2	,,	,,	92·5
72·489		2		72·6		8	,,	5·8	20947·6
62·947		1		63·1		4	1·30	,,	89·6
				53·6		1	,,	,,	21031·
39·651		1		39·8		9	,,	,,	92·8
32·507		1		32·6		3	,,	,,	21124·6
19·291		1n		19·1		6	1·29	,,	83·8
17·795		1n					,,	,,	90·5
12·087		1					,,	,,	21216·2
10·252		3		10·5		10	,,	,,	24·5
07·954		1n					,,	,,	34·8
				03·4		4	,,	5·9	55·
4688·625	4688·63	5		4688·9		12	,,	,,	21322·3
87·975	88·00	9					,,	,,	25·2
				86·1		1	,,	,,	24·
	84·44	1		84·5		6	,,	,,	41·4
83·596	83·62	2					,,	,,	45·2
67·318	67·34	1n					,,	,,	21419·6
				62·9		4	,,	,,	40·
61·962		1n					,,	,,	44·2
	59·70	1					,,	,,	54·7
57·799	57·83	2					,,	,,	63·4
				45·7		4	,,	,,	21520·
44·986	45·00	2n	4645·01			2	,,	,,	22·7
				41·1		3	,,	,,	41·
40·294	40·30	1n	40·31			1	,,	,,	44·4
			38·05			1n	,,	,,	54·9
			34·87	34·7		1	,,	,,	69·6
34·143	34·17	8	34·20		4633·91	3	,,	,,	73·1
				29·8		4	,,	,,	93·
29·227		1	29·33		29·12	1	,,	,,	95·9
			27·90			1n	,,	,,	21602·1
				27·2		3	,,	,,	05·
	26·60	3	26·62		26·42	3	,,	,,	08·4
			25·60			1	,,	,,	12·8
			22·90			1	,,	,,	23·4
					21·53	3n	,,	,,	31·9

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
				4621·0		1	1·29	5·9	21634·
			4620·10			1n	,,	,,	38·6
				15·0		3	,,	,,	62·
4614·096		1	14·20		4614·07	1n	,,	,,	66·6
			13·55			1	,,	,,	69·3
	4610·27	1n	10·30			1	,,	,,	84·6
			10·00			1	,,	,,	86·0
	09·40	1n	09·45	09·8		1	1·26	6·0	88·7
			09·32			1	,,	,,	89·2
	04·60	2	04·59	04·9	04·49	1	,,	,,	21711·6
			02·80	03·3	02·70	2	,,	,,	20·1
			02·20			3	,,	,,	22·7
					4596·39	2n	,,	,,	50·2
4590·691	4590·72	2n	4590·73	4591·1	90·66	2	,,	,,	77·2
	90·34	1n	90·35			1	,,	,,	78·8
			85·9			1n	,,	,,	21800·
			85·13			1	,,	,,	03·6
	84·41	2	84·44			1	,,	,,	07·0
				84·1		1	,,	,,	09·
82·449	82·49	2	82·50	82·2	82·50	1	,,	,,	16·2
	76·38	1	76·37			1	1·25	,,	45·3
	75·69	10	75·78	75·8	75·73	3	,,	,,	48·4
74·646		1n	74·78		74·78	4	,,	,,	53·2
				72·2	72·24	1n	,,	,,	65·
			70·9			1n	,,	,,	72·
65·599	65·64	2	65·70	65·5	65·64	2	,,	,,	97·7
			64·0		64·04	1n	,,	6·1	21904·3
	62·30	1	62·33		62·35	1	,,	,,	12·5
	58·87	1	58·90			1n	,,	,,	29·1
58·186	58·22	2	58·25		58·23	1	,,	,,	32·3
			56·46			1n	,,	,,	40·8
55·670	55·70	3	55·74		55·63	2	,,	,,	44·5
	55·30	3	55·30	55·3	55·30	2	,,	,,	46·4
			54·29		54·24	7	,,	,,	51·4
54·185		2					,,	,,	56·7
54·111		1		53·9		7	,,	,,	52·1
53·153	53·19	3	53·25		53·23	1	,,	,,	56·4
					52·58	1n	,,	,,	59·5
			50·9			1n	,,	,,	68·
50·271		2	50·2			1n	,,	,,	71·0
					49·81*	4	,,	,,	72·8
					48·98*	2	,,	,,	76·9
				48·1		1	,,	,,	81·
					44·89*	2	,,	,,	96·6
42·361	42·40	5	42·49	42·4	42·37	3	1·24	,,	22008·5
	40·17	3	40·19		40·11	1n	,,	,,	19·6
			38·9			1n	,,	,,	26·
			37·8			1n	,,	,,	31·
35·887	35·90	8	36·00	35·6	35·98	6	,,	,,	40·0
					35·00*	3	,,	,,	44·6
			33·88		34·19	1	,,	,,	49·3

* Titanium 4549·80, 4548·98, 4544·88, 4534·95.

ZIRCONIUM—*continued.*

Arc Spectrum: Wave-length: Rowland and Harrison	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Wave-length: Demarçay	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: 1/λ −	Oscillation Frequency in Vacuo
			4533·4		4533·48	1n	1·24	6·1	22051·9
					31·35	2	,,	,,	62·4
			28·2			1n	,,	,,	78·
					27·58	2	,,	,,	80·7
4526·275		1n	26·32		26·33	1 La ?	,,	,,	87·0
	4524·11	1	24·10			1	,,	,,	97·7
	23·31	1	23·33			1	,,	,,	22101·6
			23·17		23·00*	1	,,	,,	02·3
						2	,,	,,	03·1
			22·2			1n	,,	,,	07·
					20·49	2	,,	,,	15·4
			19·10			1	,,	,,	22·2
					18·26*	2	,,	,,	26·3
			16·03			1	,,	,,	37·2
			15·62			1	,,	,,	39·2
			13·56			1n	,,	,,	49·4
			13·08		12·98	1	,,	,,	56·9
07·260	07·32	7	07·39	4507·2	07·33	3	,,	,,	79·5
			04·3		04·23	1n	1·23	,,	95·2
			04·07			1n	,,	,,	96·0
			01·7			1b	,,	,,	22207·7
					01·47*	2	,,	,,	08·9
			00·9			1n	,,	,,	12·
			4499·2			1b	,,	,,	20·
4497·149	4497·16	5	97·27	4497·3	4497·22	9	,,	6·2	29·9
95·598		1	95·76		95·69	2	,,	,,	37·4
	95·14	1					,,	,,	40·0
94·560		3	94·78	94·8	94·75	8	,,	,,	42·3
	91·74	1	91·78		91·75	1	,,	,,	56·8
90·402		1n	90·47		90·53	1n	,,	,,	63·2
					89·38	2	,,	,,	68·6
					88·55	2	,,	,,	72·7
85·577		1n	85·71	86·2	85·76	2	,,	,,	87·0
				84·4Pt?	84·45	2n	,,	,,	93·1
			82·72		82·56	1	,,	,,	22302·1
82·180		1n	82·28			2	,,	,,	04·1
				81·7	81·58	2	,,	,,	07·3
	80·95	1	81·00		80·95	1	,,	,,	10·4
			78·66			1	,,	,,	21·9
			75·48			1	,,	,,	37·8
				71·1		8	,,	,,	60·
70·698	70·72	4	70·80		70·72	5	,,	,,	61·5
70·461	70·46	2	70·52			2	,,	,,	62·8
69·664		1n	69·75		69·70	1n	,,	,,	66·7
	68·95	2	68·98			1	1·22	,,	70·3
					68·69	?	,,	,,	71·7
68·364	68·38	2	68·42			1	,,	,,	73·3
67·054	67·07	3	67·12	67·1	67·13	2	,,	,,	75·6
			66·62			1	,,	,,	82·1
			64·35			1	,,	,,	93·5
	61·37	3	61·50	61·2	61·44	5	,,	,,	22408·1

* Titanium 4523·00, 4518·25, 4501·46.

ZIRCONIUM—*continued.*

Arc Spectrum: Wave-length: Rowland and Harrison	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Wave-length: Demarçay	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4460·930		1					1·22	6·2	22410·7
60·495	4460·52	3	4460·57		4460·57	2	,,	,,	12·6
	59·19	2	59·22			1	,,	,,	19·4
	58·04	1					,,	,,	25·2
57·562	57·58	4	57·71	4457·5	57·66	5	,,	,,	27·3
56·438	56·44	2	56·50		56·50	2	,,	,,	33·1
55·574	55·60	2	55·64		55·59	2	,,	,,	37·4
54·939	54·97	5	55·08	55·1	55·00	3Ca?	,,	,,	40·5
					53·89*	5	,,	,,	46·1
					53·52*	2	,,	,,	48·0
					51·12*	2	,,	,,	60·1
	50·46	3	50·49	50·6	50·49	2	,,	,,	63·3
	49·10	1	49·14		49·31	2	,,	,,	69·8
			48·18			1	,,	,,	74·9
					47·34	1n	,,	,,	79·2
			46·59			1	,,	,,	82·9
			44·74			1	,,	,,	92·3
	44·46*	1	44·53			1	,,	,,	93·5
					43·98	2	,,	,,	96·1
	43·17	5	43·31	43·4	43·25	10	,,	,,	99·9
	42·67	1	42·70			1	,,	,,	22502·7
	40·60	3	40·80	40·6	40·72	5	,,	,,	12·8
	38·19	3	38·23		38·33	2	,,	,,	25·2
				37·8Pt?			,,	,,	27·5
36·910	36·89	1n	36·94		37·09	1	,,	,,	31·8
			36·55			1	,,	,,	33·8
35·986	36·00	1n			36·16	1	,,	,,	36·4
			35·7			1n	,,	,,	38·2
31·629	31·63	4	31·70	31·9	31·74	3	,,	6·3	58·5
	31·25	1	31·30			1	,,	,,	60·6
				30·1Pt?		1	1·21	,,	66·5
			29·55		29·53	2	,,	,,	69·4
29·245	29·24	2	29·28		29·34	2Ca?	,,	,,	70·8
27·383	27·42	3	27·44	27·5	27·49	3	,,	,,	80·2
					26·26*	1n	,,	,,	86·1
			22·97			1	,,	,,	22602·9
			21·22			1	,,	,,	11·8
20·598	20·61	4	20·70	20·4	20·65	3	,,	,,	14·9
			19·50			1	,,	,,	20·7
			18·40			1	,,	,,	26·3
			17·6			2n	,,	,,	30·4
			16·10			1	,,	,,	38·1
14·675	14·70	3	14·80		14·75	4r	,,	,,	45·1
14·449	14·29	2n	14·37	14·4		4	,,	,,	47·0
	13·20	4	13·28	13·0	13·24	3	,,	,,	52·8
	12·10	1	12·15			1	,,	,,	58·5
	11·78	1	11·83	11·6		1	,,	,,	60·2
	09·79	1	09·82			1	,,	,,	70·4
	08·54	4	08·50			1	,,	,,	77·0
			04·98			2	,,	,,	95·3
03·482	03·50	2n	03·67		03·63	5	,,	,,	22702·6

* Titanium 4453·91, 4453·52, 4451·53, 4444·0, 4426·20.

ZIRCONIUM—*continued.*

Arc Spectrum: Wave-length: Rowland and Harrison	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Wave-length: Demarçay	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
	4403·13	2	4403·16	4403·3		1	1·21	6·3	22704·7
4401·491	01·52	1	01·57		4401·54	2	,,	,,	13·1
	01·04	1	01·10			1	,,	,,	15·4
00·375	00·40	3	00·45		00·42	2	,,	,,	18·9
	4399·60	1	4399·62	4399·7		1	,,	,,	23·0
				97·2		6	,,	,,	35·
	95·40	3	95·42			2	,,	,,	44·7
					4395·22*	5	,,	,,	45·7
4395·076	95·10	3	95·14			2	,,	,,	46·3
	94·67	2	94·73			1	,,	,,	48·4
				91·7	91·12	2Th?	1·20	,,	66·9
					90·68	2	,,	,,	69·2
	90·33	1	90·36			1	,,	,,	71·0
89·756	89·75	1n	89·81		89·72	2	,,	,,	74·0
	88·65	1	88·72			2	,,	,,	79·6
	86·63	1	86·70			1	,,	,,	90·1
			84·53			1n	,,	,,	22801·2
			84·4			1n	,,	,,	01·8
			83·35			1	,,	,,	07·3
			83·20			1	,,	,,	08·1
79·909	79·91	7	80·12	80·1	79·98	10	,,	,,	25·1
			75·7			1b	,,	,,	47·2
73·213	73·26	2	73·28		73·27	1	,,	,,	60·0
	72·70	1	72·73			1	,,	,,	62·8
71·088	71·14	6	71·27	71·1	71·17	7	,,	,,	70·9
			68·7			1n	,,	6·4	84·
			68·1			1n	,,	,,	87·
66·581	66·63	5	66·69	66·8	66·63	3r	,,	,,	94·5
			64·50			1n	,,	,,	22905·7
			64·30			1n	,,	,,	06·8
	62·14	1	62·19			1	,,	,,	18·0
	61·00	5	61·01	60·9	61·07	3	,,	,,	24·0
60·437		4					,,	,,	27·1
59·862	59·91	7	60·05	60·2	60·01	10Gr	,,	,,	29·2
	59·47	1					,,	,,	32·1
58·880	58·92	3	58·95		59·01	2Yt	,,	,,	35·1
			56·6			1b	1·19	,,	47·
			55·7			1b	,,	,,	52·
	54·08	1	54·08	54·4		1	,,	,,	60·6
			50·71			1	,,	,,	78·4
	49·09	2	49·10			1	,,	,,	86·9
48·019	48·03	8r	48·15	48·3	48·22	5	,,	,,	91·9
			47·53		47·47	1n	,,	,,	95·3
47·479	47·42"	2n	47·42			1	,,	,,	95·6
47·359		1					,,	,,	96·1
46·651	46·67	2	46·70		46·81	2	,,	,,	99·5
					45·90	1n	,,	,,	23003·8
	45·71	1	45·69			1	,,	,,	04·6
	45·13	1n			45·32	1n	,,	,,	06·4
43·527	43·55	1n	43·59		43·69	1	,,	,,	16·1

* Titanium 4395·19.

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
4343·170	4343·20	2	4343·23		4343·39	2	1·19	6·4	23017·8
	42·82	1	42·80			1	,,	,,	20·2
42·366	42·40	1n	42·42		42·50	2	,,	,,	22·2
41·258	41·31	6r	41·40	4341·7	41·32	4	,,	,,	28·0
	40·64	1n	40·7			1n	,,	,,	31·7
	39·70	1	39·80		39·74	3Gr?	,,	,,	36·4
	39·29	1					,,	,,	38·8
37·751	37·80	1	37·90	38·2	37·91	4	,,	,,	41·2
	36·89	1	36·87	36·9		1n	,,	,,	51·7
36·473		1n	36·54		36·55	1nCe?	,,	,,	53·6
	36·26	1	36·30			1	,,	,,	54·8
			34·9			1n	,,	,,	62·2
33·390	33·45	2	33·59	33·7	33·46	7	,,	,,	69·8
29·695	29·72	2	29·76		29·81	2	,,	,,	89·6
			27·65			1	,,	,,	23100·8
25·564	25·60	4	25·62	25·8	25·63	4	,,	,,	11·8
24·156	24·20	3	24·24	24·2	24·17	2	,,	,,	19·3
			23·81			2	,,	,,	21·3
	23·15	1	23·19			1	,,	,,	24·8
					22·81	2La?	,,	,,	26·7
			22·50			1	,,	,,	28·4
	21·63	1n	21·62			1	,,	,,	33·0
21·298	21·34	2	21·35		21·28	2	,,	,,	34·7
				21·1		1	,,	,,	36·
			20·9			1n	,,	,,	36·9
				19·6	19·82	1n	,,	,,	42·7
19·175	19·22	2	19·24		19·21	1	,,	,,	46·0
17·435	17·48	4	17·57	17·5	17·47	6	1·18	,,	55·2
					15·10*	5	,,	,,	68·0
	14·12	1	14·17			1	,,	,,	73·2
				13·0	13·08	2	,,	,,	78·9
12·354	12·40	1	12·47		12·38	2	,,	,,	82·5
			11·02			1	,,	,,	90·0
09·944	09·98	2	09·99		09·96	2Ce?	,,	,,	95·6
			09·36			1	,,	,,	98·9
	09·25	1	09·20	09·4		4	,,	,,	99·6
	09·11	1			09·11	3	,,	,,	23200·2
			68·13			1	,,	6·5	05·4
	07·60	1	07·62			1	,,	,,	08·2
	07·39	1	07·42			1	,,	,,	09·2
	06·79	1	06·4			1b	,,	,,	12·6
06·048		1			06·04*	3	,,	,,	16·6
05·817	04·89	4	04·92	05·0	04·82	4	,,	,,	17·9
							,,	,,	23·0
	03·60	1	03·60			1	,,	,,	29·9
03·005	03·10	5	03·12	03·1	02·99	5	,,	,,	32·8
	02·76	1	02·80			1	,,	,,	34·3
	02·00	2	02·10	02·1	01·96	5	,,	,,	38·4
	01·75	2					,,	,,	39·9
			01·2		01·21	1n	,,	,,	42·8
00·696	00·73	1n	00·76		00·66	2	,,	,,	45·5

* Titanium 4315·12, 4306·04.

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
					4300·04	2	1·18	6·5	23249·1
					4298·80*	2	,,	,,	55·8
			4297·00	4297·1		6	,,	,,	65·5
4296·927	4296·92	2			96·86	2Ce?	,,	,,	66·7
	95·38	1		95·5	95·98*	2	,,	,,	72·7
94·914	94·99	6	95·08		94·98	5	,,	,,	76·7
	94·65	1	94·67			1	,,	,,	78·2
	93·31	2	93·41	93·8	95·35	5	,,	,,	85·3
				92·1		3	,,	,,	92·
91·470	91·57	3	91·54		91·53	3	,,	,,	95·2
	91·40	3	91·38			1	,,	,,	96·0
					91·20*	2	,,	,,	97·0
90·332	90·38	1n	90·41		90·45	2	,,	,,	23301·4
				89·8	89·94	1Ce?	,,	,,	03·8
89·284	89·32	1n	89·45		89·33	2	,,	,,	06·5
					87·54	2	,,	,,	16·9
86·634	86·67	2n	86·78	87·1	86·71	3	,,	,,	21·5
					86·20*	2	,,	,,	24·2
85·373	85·41	2n	85·44	85·7	85·46	1nCe?	,,	,,	28·4
	84·92	1	84·95			1	,,	,,	31·1
82·326	82·36	8	82·53	82·8	82·33	8	,,	,,	45·0
	80·50	1	80·51			1	1·17	,,	55·2
77·487	77·52	2	77·60	77·8	77·50	3Th?	,,	,,	71·5
	76·88	3	76·91		76·86	2	,,	,,	75·0
74·884	74·91	3	74·95		74·92	2Cr?	,,	,,	85·8
73·643	73·69	4	73·80	74·1	73·68	5	,,	,,	92·4
			73·07			1	,,	,,	95·9
	72·42	1	72·48			1	,,	,,	99·3
			70·37			1	,,	,,	23410·7
			69·90			1	,,	,,	13·2
			69·40			1	,,	,,	16·0
68·141	68·20	5	68·22	68·4	68·19	5	,,	,,	22·6
	67·46	1	67·55			1	,,	,,	26·4
			67·2 C			2b	,,	,,	28·1
66·853	66·90	1	66·96		66·97	2	,,	,,	29·6
	65·95	1					,,	,,	34·9
			65·17	65·2	65·13	2	,,	,,	39·3
65·041	65·05	1					,,	,,	39·9
64·141	64·20	1n	64·23		64·33	2	,,	,,	44·4
	62·13	1			63·36*	2	,,	,,	49·2
61·553	61·63	2	61·65		61·67	2	,,	,,	58·7
61·331	61·35	2	61·42	61·5	61·47	3	,,	,,	60·0
	60·95	1					,,	,,	62·4
58·171	58·22	5	58·31	58·5	58·22	7	,,	,,	77·4
				57·3		1	,,	,,	82·6
56·575	56·60	3	56·66		56·67	2	,,	,,	86·3
	56·18	1	56·26			1	,,	,,	88·5
	55·50	1	55·55			1	,,	,,	92·4
				54·3	54·55	3Cr?	,,	,,	97·7
53·690	53·71	3	53·76		53·76	2	,,	,,	23502·3
			50·89			1	,,	6·6	17·9

* Titanium 4298·89, 4295·93, 4291·19, 4286·19, 4263·31.

ZIRCONIUM—*continued.*

Arc Spectrum: Wave-length: Rowland and Harrison	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Wave-length: Demarçay	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
			4249·55			1n	1·17	6·6	23525·3
	4248·38	1					,,	,,	31·8
			46·50			1n	,,	,,	42·2
			46·65			1n	,,	,,	47·4
			44·4			1b	,,	,,	54·
	43·71	1	43·74			1	1·16	,,	57·6
	42·78	1	42·83			1	,,	,,	62·7
	42·20	1n					,,	,,	66·1
4241·803	41·83	6	41·98	4242·1	4241·99	7	,,	,,	67·7
41·319	41·37	6	41·50		41·41	4	,,	,,	70·5
40·454	40·52	8r	40·59	40·6	40·57	3	,,	,,	75·3
39·428	39·49	9r	39·58	39·7	39·60	6	,,	,,	81·0
					37·72	3	,,	,,	91·0
37·554	37·59	2	37·57			2	,,	,,	91·8
	36·71	3	36·81	36·8	36·89	4	,,	,,	96·1
					36·37	5	,,	,,	98·5
36·190	36·21	4	36·23			2	,,	,,	99·2
34·755	34·79	3	34·89	35·1	34·90	3	,,	,,	23607·1
	32·67	1n	32·64			1	,,	,,	19·2
	32·25	1		32·2		7	,,	,,	21·5
31·755	31·79	2	31·88		31·88	6	,,	,,	23·8
31·683		4					,,	,,	24·9
	30·33	1n	30·37			1	,,	,,	32·1
27·880	27·94	10	27·98	28·3	27·99	7	,,	,,	45·7
	26·58	1	26·58			1	,,	,,	53·8
	25·70	2	25·67	25·7		1	,,	,,	58·2
	25·40	1	25·40			1	,,	,,	59·8
	24·85	2	24·8			1n	,,	,,	62·9
	24·41	2	24·42	24·5		2	,,	,,	65·3
	22·61	1	22·67	22·6		2	,,	,,	75·3
	20·81	2	20·30	20·6		1	,,	,,	87·0
			20·08			1	,,	,,	89·6
	18·60	3	18·60	18·7		2	,,	,,	97·9
			17·45	17·1		1n	,,	,,	23704·4
			15·95	16·1		1	,,	,,	12·8
			15·50			1	,,	,,	15·4
			14·58			3	,,	,,	21·5
	14·05	5		14·3	14·15	6	,,	,,	23·3
			13·45			1n	,,	,,	26·9
			12.79		12·95	2	,,	,,	30·2
			12·17	12·2	12·17	7	,,	,,	34·1
	12·06	3					,,	,,	34·7
			11·50		11·58	1	,,	,,	37·7
				11·1		2	,,	,,	40·2
			10·87		10·92	3	,,	,,	41·3
			10·50			1	,,	,,	43·5
	09·13	4	09·21	09·4	09·23	10	,,	,,	50·9
			03·30			1	,,	,,	56·0
			06·20	06·2	06·20	2	,,	,,	67·8
			05·00			1n	1·15	,,	74·6
	01·63	6	01·69	01·8	01·71	6	,,	,,	93·4
	4199·24	6	4199·30	4199·5	4199·34	5	,,	6·7	23806·8
			98·5	98·2		1n	,,	,,	12·2

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			4197·95			1n	1·15	6·7	23814·4
			96·50	4196·6	4196·43	3Ce?	,,	,,	22·9
4196·297		3	96·32			1	,,	,,	23·8
94·925	4194·95	4	95·00	95·1	95·00	5	,,	,,	31·4
			94·66			1	,,	,,	33·1
94·163		2	94·20		94·23	2	,,	,,	35·8
			92·30			1	,,	,,	46·5
91·947		1	92·03	91·9	92·01	2	,,	,,	48·3
91·650		2	91·75		91·77	3	,,	,,	49·9
	87·69	5	87·80	87·7	87·67	6	,,	,,	72·6
			87·30			1	,,	,,	75·0
86·834		2	86·89	87·0	86·83	6Ce?	,,	,,	77·6
			86·25			1	,,	,,	81·0
			84·62			1	,,	,,	90·3
83·472	83·49	4	83·51	83·5	83·43	3	,,	,,	96·9
82·722		5	82·75			1n	,,	,,	23901·0
	81·09	3n	81·13			1n	,,	,,	10·4
79·964		3	80·08	80·2	79·93	8	,,	,,	16·8
			77·75			1n	,,	,,	29·6
			74·56			1	,,	,,	47·9
			73·36			1	,,	,,	54·8
71·625		3	71·65	71·6	71·63	3U?	,,	,,	64·7
			70·75			1n	,,	,,	69·8
69·503		1	69·55	69·6	69·49	2	,,	,,	76·9
			68·90			1n	1·14	,,	80·4
			68·40			1n	,,	,,	83·3
			67·88			1n	,,	,,	86·3
			67·30			1n	,,	,,	89·6
66·509	66·58	4	66·60	66·6	66·51	5	,,	,,	93·9
			65·80			1n	,,	,,	98·3
			65·55			1n	,,	,,	99·7
					63·98	1n	,,	,,	24008·8
			63·6			1n	,,	,,	11·0
			62·60			1	,,	,,	16·7
61·352	61·40	6	61·48	61·4	61·45	9	,,	,,	23·5
	60·06	1					,,	,,	31·4
			59·77			1	,,	,,	32·9
			59·10			1	,,	,,	37·0
			57·93			1	,,	,,	43·7
56·383	56·40	6	56·49	56·7	56·49	8	,,	,,	52·3
			55·30			1	,,	,,	58·9
			53·96	53·8		1	,,	,,	66·7
52·793	52·83	4	52·87	52·9	52·89	3La?	,,	,,	73·2
	52·46	2n					,,	,,	75·4
51·123	51·18	4	51·23	51·0	51·18	7	,,	,,	82·9
49·443	49·35	8	49·43	49·6	49·45	14	,,	,,	93·1
					47·94	2	,,	,,	24101·7
			47·53			1	,,	6·8	03·9
46·038		1n			46·12	1n	,,	,,	12·4
			45·30			1n	,,	,,	16·9
			43·39	43·4		1	,,	,,	28·0
40·161		2	40·18	40·5	40·22	2b	,,	,,	46·7
			37·20			1	,,	,,	64·1

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		λ +	$\frac{1}{\lambda}$ −	
4135·830	4135·86	4	4135·85	4135·9	4135·88	2	1·14	6·8	24172·0
			34·46	34·4		2	,,	,,	80·2
			33·91			1	,,	,,	83·4
			33·16		33·19	1nCe?	,,	,,	87·7
			32·14	32·2		1	,,	,,	93·7
			31·50			1	,,	,,	97·5
			30·63			1	1·13	,,	24202·6
28·127		1	28·08	28·0	28·08	2nV?	,,	,,	17·5
			23·53	23·7		1	,,	,,	44·3
			22·70			1	,,	,,	49·1
			21·87			1	,,	,,	54·0
21·603	21·61	5	21·68	21·8	21·55	5Ce?	,,	,,	55·5
20·311		1	20·38		20·32	2	,,	,,	63·1
	20·00	2	19·99	19·9	19·92	2Ce?	,,	,,	64·7
					19·38	2	,,	,,	68·7
					14·55	2	,,	,,	97·2
13·117		1					,,	,,	24305·7
					12·84	2	,,	,,	07·3
				11·7	12·19	2	,,	,,	11·1
10·803		1	10·84		10·85	2	,,	,,	19·2
10·197		1	10·29	10·1	10·19	3	,,	,,	22·8
08·546	08·55	3	08·60	08·5	08·59	3Th?	,,	,,	32·5
07·692	07·69	3	07·75	07·7	07·73	3	,,	,,	37·6
				03·5		1	,,	,,	62·6
			02·7			1b	,,	,,	67·4
4099·460	4099·47	2	4099·50	4099·3	4099·52	2	,,	6·9	86·4
96·783	96·77	2	96·80	96·5	96·85	4	,,	,,	24402·4
			96·33			1	,,	,,	05·2
94·418	94·45	2	94·42	94·3	94·48	2	,,	,,	16·4
93·313	93·32	2	93·32		93·40	2	1·12	,,	23·0
90·945	90·98	3	91·00		90·97	3	,,	,,	37·2
90·664	90·69	5	90·70	90·7	90·68	6	,,	,,	38·9
	88·34	1	88·3			1n	,,	,,	52·9
87·838	87·85	2	87·88	87·8	87·88	2	,,	,,	55·8
85·840	85·83	3	85·89	85·9	85·91	4	,,	,,	67·7
84·452	84·47	3	84·50	84·3	84·48	3	,,	,,	76·0
83·241	83·25	2	83·29	83·0	83·28	2Ce?	,,	,,	83·3
82·441	82·46	2	82·45		82·51	2	,,	,,	88·2
					81·98	2	,,	,,	90·9
81·361	81·40	10	81·48	81·3	81·38	7	,,	,,	94·5
			80·64			1	,,	,,	99·1
			80·3			1n	,,	,,	24501·1
78·457	78·48	4	78·49	78·1	78·51	3	,,	,,	12·0
77·201		2	77·27		77·25	3	,,	,,	19·5
76·678	76·70	3	76·70	76·6	76·74	3	,,	,,	22·7
			75·20		75·14	4	,,	,,	32·0
75·072	75·10	4	75·09	74·9		4	,,	,,	32·4
72·842	72·89	9	72·90	72·8	72·89	7	,,	,,	45·7
71·242	71·25	2	71·30	70·9	71·26	3	,,	,,	55·5
			69·73			1	,,	,,	64·8
68·872	68·87	2	68·90	68·8	68·93	2Ce?	,,	,,	69·8
			68·10			1	,,	,,	74·6
			65·37			1	,,	,,	91·1

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda+$	$\frac{1}{\lambda}-$	
4064·303	4064·34	7	4064·38	4064·1	4064·31	7	1·12	6·9	24597·4
	63·49	1n	63·47			1	,,	,,	24602·6
			62·83			1	,,	,,	06·5
61·678	61·70	4	61·70	61·5	61·66	4	,,	,,	13·5
60·730	60·75	2	60·78		60·72	2	,,	,,	19·1
				60·4		3	,,	,,	21·2
					60·32	2	,,	,,	21·7
60·233	60·25	2	60·25″			1	,,	,,	22·2
			59·37			1n	,,	,,	27·5
58·771	58·83	2	58·78	58·4	58·80	2	,,	,,	30·9
			58·30			1	,,	,,	34·0
57·984		2			57·94	2	,,	,,	36·0
56·655	56·65	1	56·65		56.60	2	,,	,,	44·0
55·851	55·88	4	55·90	55·6	55·84	5	,,	,,	48·7
55·173	55·20	5	55·20	54·9	55·16	5	1·11	,,	52·9
54·581	54·60	3	54·60		54·54	2	,,	,,	56·6
			53·3			1n	,,	,,	64·4
			52·9			1n	,,	,,	66·8
	50·67	3					,,	7·0	80·3
50·467	50·51	3	50·52	50·4	50·46	7	,,	,,	81·4
49·716		5					,,	,,	86·1
48·813	48·80	6	48·93	48·7	48·78	9	,,	,,	91·5
			48·15			1n	,,	,,	95·6
45·972	46·26	2	46·3			1n	,,	,,	24708·1
45·758	45·78	5	45·90	45·6	45·92	8Ce?	,,	,,	09·7
	44·73	5	44·80	44·6	44·76	4	,,	,,	16·3
43·722	43·71	5	43·80	43·5	43·78	4	,,	,,	22·5
42·373	42·39	3	42·49	42·1	42·45	3	,,	,,	30·6
41·789	41·80	2	41·90	41·7	41·82	2	,,	,,	34·3
40·388	40·40	2	40·49	40·3	40·46	3	,,	,,	42·8
			39·7	39·3		1b	,,	,,	48·5
			38·35			1n	,,	,,	55·6
			36·70			1	,,	,,	65·7
36·039	36·03	5	36·10	35·9	36·10	4	,,	,,	69·6
			35·01			1	,,	,,	76·1
34·231	34·24	3	34·30	34·0	34·34	3	,,	,,	80·6
			33·8			1n	,,	,,	83·5
32·211		1n		32·1	32·25	2	,,	,,	93·2
32·197		4					,,	,,	93·4
31·497		1	31·57		31·58	2Ce?	,,	,,	97·4
				31·1		1	,,	,,	24800·1
	30·87	2	30·87			2	,,	,,	01·5
30·188	30·20	4	30·26		30·21	3	,,	,,	05·5
39·821	29·81	5	29·88	29·8	29·85	7	,,	,,	07·9
	29·08	4	29·17	29·1	29·19	3	,,	,,	12·1
28·099		3					,,	,,	18·6
27·350	27·35	5	27·40	27·2	27·42	5	,,	,,	23·0
25·060	25·07	5	25·16		25·13	3	,,	,,	37·1
24·583	24·57	3	24·70	24·9	24·66	8	,,	,,	40·0
	24·14	5	24·20	24·1	24·20	5	,,	,,	42·8
	23·45	1	23·47			1	,,	,,	47·2
	23·20	1	23·22			1	,,	,,	48·1
			22·6			1n	,,	,,	51·9

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			4021·15			1n	1·11	7·0	24861·5
	4020·44	1	20·51	4020·6		1	,,	,,	65·7
4018·520	18·50	2	18·60	18·4	4018·56	5	,,	,,	77·6
	18·25	1					,,	,,	79·5
			17·49			2n	,,	,,	84·2
	17·10	3	17·16	17·0		4	,,	,,	86·4
			16·10			1	,,	,,	92·8
			13·99			1	1·10	,,	24905·9
12·395	12·41	4	12·48	12·2		4	,,	,,	15·6
			10·96	10·7		1	,,	,,	24·8
	09·54	1	09·56	09·0		1	,,	,,	33·5
	07·73	4	07·80	07·6		4	,,	,,	44·6
	05·00	2n	05·02			2n	,,	,,	61·7
				04·8		4	,,	,,	63·0
	04.54	2	04·51			2	,,	,,	64·8
	03·22	3	03·28	03·2		3	,,	7·1	72·6
	02·69	3	02·68			2	,,	,,	76·1
	01·33	2	01·37			1	,,	,,	84·5
	01·23	2	01·21	01·1		2	,,	,,	85·3
	3999·09	3	3999·18	3999·1		14	,,	,,	98·3
	98·81	1					,,	,,	25000·4
			96·98			1	,,	,,	11·8
			94·26			1	,,	,,	28·8
			93·23			1	,,	,,	35·3
	92·59	1n	92·6			2n	,,	,,	39·3
	92·18	1n	92·2			1n	,,	,,	41·9
3991·268	91·25	6	91·31	91·3		14	,,	,,	47·5
	89·62	3	89·65	89·5		3	,,	,,	57·8
	89·39	2	89·39	89·5		3	,,	,,	59·4
	88·79	2	88·80	88·8		2	,,	,,	63·1
			88·31			1	,,	,,	66·2
	87·95	1	87·94			1	,,	,,	68·5
			87·4			1n	,,	,,	71·9
	86·95	1	86·96	86·7		1	,,	,,	74·9
			86·22			1	,,	,,	79·3
	84·87	3	84·90	84·8		3	,,	,,	87·7
			84·15			1	,,	,,	92·3
			83·45			1	,,	,,	96·8
82·304	82·28	2	82·30			2	,,	,,	25104·0
			82·20	82·0		3	,,	,,	04·7
81·726	81·70	8n	81·79	81·7		4	,,	,,	07·6
			79·7			1n	,,	,,	20·4
79·374		3	79·50			1n	,,	,,	22·1
	78·85	2	78·86	78·7		2	,,	,,	25·8
	78·37	1	78·35			2	,,	,,	28·9
	77·60	3	77·60	77·6		3	,,	,,	33·7
77·421	77·48	2					,,	,,	34·8
	76·34	1	76·30	76·2		1	,,	,,	41·8
75·434	75·43	4	75·47	75·3		4	1·09	,,	47·3
			74·97			1	,,	,,	50·3
			74·3			1n	,,	,,	54·6
	73·63	10	73·68	73·7		5	,,	,,	58·7
73·549	72·46	2	72·43	72·4		2	,,	,,	59·8

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			3971·00			1n	1·09	7·1	25175·5
			68·61Ca			2	,,	,,	90·6
	3968·39	4	68·39	3968·4		6	,,	,,	92·0
	66·81	5	66·80			3	,,	,,	25202·1
3966·417		1n					,,	,,	04·6
			65·07			1	,,	,,	13·1
	63·85	2b	63·90	63·8		2n	,,	,,	20·7
			62·4			1n	,,	,,	30·1
			61·71	61·7		6	,,	,,	34·5
			60·82			1	,,	,,	40·2
58·354	58·34	6	58·39	58·6		14	,,	,,	55·9
	57·53	1	57·50			1	,,	,,	61·3
	56·93	1	56·90			2	,,	,,	65·1
			55·94			1	,,	7·2	71·2
	55·75	1	55·79			1n	,,	,,	72·2
				54·4		1	,,	,,	81·1
	53·00	1n	53·00	52·8		1	,,	,,	90·0
			51·96			1	,,	,,	96·7
	51·46	1n	51·45	51·4		1	,,	,,	99·9
			49·7	49·2		1b	,,	,,	25311·2
				47·4		1	,,	,,	25·9
			46·96			1	,,	,,	28·8
			46·4	46·3		1b	,,	,,	32·0
			46·2			1b	,,	,,	33·6
			45·5			1b	,,	,,	38·1
			45·2			1b	,,	,,	40·1
			44·14			1	,,	,,	46·9
	42·95	1	42·96			1	,,	,,	54·5
			42·09			3	,,	,,	60·1
				41·9		5	,,	,,	61·3
41·758	41·76	3	41·75			3	,,	,,	62·2
			40·78			1	,,	,,	68·5
			39·8	39·7		1b	,,	,,	75·1
			38·9			1b	,,	,,	80·6
			38·3			1b	,,	,,	84·5
36·191	36·21	2	36·28	36·1		4	1·08	,,	97·8
34·919	34·93	3	34·99			4	,,	,,	25406·1
34·254	34·27	3	34·39	34·5		6	,,	,,	10·2
			33·8 Ca			3	,,	,,	13·5
	33·36	1	33·34			2	,,	,,	16·4
			32·52			1n	,,	,,	21·8
			31·55	31·7		1n	,,	,,	28·0
			31·07			1n	,,	,,	31·2
29·666	29·71	8	29·71	29·8		7	,,	,,	40·1
	27·59	1	27·60	27·2		2	,,	,,	53·7
	26·90	1b	26·96			2n	,,	,,	58·0
			25·8			1n	,,	,,	65·3
	25·03	1	25·02			1	,,	,,	70·4
			24·05			2	,,	,,	77·0
			23·65	23·7		1	,,	,,	79·3
			23·27			1	,,	,,	81·7
			22·51			1	,,	,,	86·7
21·928	21·99	5	21·99	21·8		5	,,	,,	90·2

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			3921·17			1	1·08	7·2	25495·4
			20·35			1	,,	,,	25500·7
			18·25	3918·3		1	,,	,,	14·4
			17·63			1	,,	,,	18·4
	3916·77		16·80	16·8		2	,,	,,	23·9
3916·067	16·10	5	16·16	16·2		8	,,	,,	28·2
			14·59	14·3		6	,,	,,	38·3
			12·3			2n r	,,	,,	53·2
				11·5		8	,,	,,	58·4
			09·1			1n	,,	7·3	74·0
			08·25	08·4		1n	,,	,,	79·6
				07·9		1	,,	,,	81·9
			06·30	06·3		1	,,	,,	92·4
			03·92			1	,,	,,	25608·0
	01·64	4	01·70	01·8		1n	,,	,,	22·7
00·649		5	00·71	00·9		6	,,	,,	29·2
			00·08			1	,,	,,	33·2
	3898· 6	1	3898·72			1	,,	,,	42·3
			98·07	98·1		2	,,	,,	46·4
3897·798	97·80	1	97·82			2	,,	,,	48·8
96·664	96·67	2	96·73	96·9		3	1·07	,,	55·5
			94·52			1	,,	,,	69·8
			94·00″	93·9		2	,,	,,	73·2
			92·66			1	,,	,,	82·1
92·161	92·14	1n	92·19			2	,,	,,	85·3
91·516	91·53	5	91·61	91·6		6	,,	,,	89·4
	90·49	10	90·58	90·5		7	,,	,,	96·1
			89·62			1	,,	,,	25702·1
			89·47			1	,,	,,	03·1
	85·53	6	85·61	85·8		7	,,	,,	28·9
			82·20	82·3		6	,,	,,	51·3
				81·2		1	,,	,,	57·9
	79·20	2	79·21	3879·2		4	,,	,,	71·2
	77·70	3	77·78	77·7		7	,,	,,	80·6
			74·56	74·6		1	,,	,,	25802·4
				72·4		1	,,	,,	16·5
				67·2		1	,,	,,	51·2
			64·57	64·6		6	,,	,,	68·8
	64·01	3	64·12	64·1		7	,,	,,	72·2
				61·2		1	,,	,,	91·4
			55·61	55·7		3	1·06	,,	25928·9
			53·30	53·4		3	,,	,,	44·5
			52·60			1	,,	,,	49·2
	49·41	3	49·48	49·5		6	,,	,,	70·5
			48·83			1n	,,	,,	74·7
	47·13	3	47·22	47·2		6	,,	,,	85·8
				45·1		1	,,	,,	99·8
			43·30	43·3		9	,,	,,	26012·0
			38·49	38·5		5	,,	,,	44·6
			36·98	37·2		12	,,	,,	54·9
	36·12	4	36·18	36·3		5	,,	,,	60·5
			34·00	34·1		2	,,	,,	75·1
				32·4		1	,,	,,	86·0

ZIRCONIUM—*continued.*

Arc Spectrum: Wave-length: Rowland and Harrison	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Wave-length: Demarçay	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}$−	Oscillation Frequency in Vacuo
				3831·5		1	1·06	7·3	26092·1
				30·9		1	,,	,,	96·2
				29·3		1	,,	,,	26107·1
			3827·65	27·6		3	,,	,,	18·4
			27·40	–		2	,,	,,	20·1
			25·91	25·6		3	,,	,,	30·3
			24·90			2	,,	,,	37·2
			24·55			2	,,	,,	39·6
				23·7		2	,,	,,	45·4
	3822·53	3	22·60	22·7		6	,,	,,	53·1
				20·9		1	,,	,,	64·5
			20·00	20·0		1	,,	,,	70·7
			18·90			1	,,	,,	78·2
				18·0		9	,,	7·4	84·3
			17·80			6	,,	,,	85·7
			16·86	17·0		2	,,	,,	92·1
			15·18	15·3		3	,,	,,	26203·7
			14·15	14·4		1	,,	,,	10·8
			09·85	10·0		2	,,	,,	40·3
			08·38	08·8		3	,,	,,	50·5
			07·55	07·7		3	,,	,,	56·2
				06·5		2	,,	,,	63·4
				01·5		3	,,	,,	98·0
			00·91			6	,,	,,	26302·2
			3796·71	3797·1		9	,,	,,	31·2
			93·53			2	,,	,,	53·3
			92·55	92·7		4	1·05	,,	60·1
	3791·53	4	91·60	91·8		6	,,	,,	67·0
			90·13	90·5		1	,,	,,	76·9
				88·8		1	,,	,,	86·2
				87·4		2	,,	,,	95·9
			86·80			6	,,	,,	26400·1
				85·5		2	,,	,,	09·2
				84·8		5	,,	,,	14·1
			82·97	83·4		5	,,	,,	26·9
			82·48	82·7		4	,,	,,	30·3
			81·80			1	,,	,,	35·0
	80·71	8	80·78	31·1		6	,,	,,	42·4
			77·82			1	,,	,,	62·9
			76·17			1n	1·04	,,	74·5
			75·61			1n	,,	,,	78·4
			74·75			1	,,	,,	84·4
			74·25			1	,,	,,	87·9
			73·7			1n	,,	,,	91·8
			72·29	72·6		6	,,	,,	26501·7
			71·53			1	,,	7·5	06·9
			68·05	68·3		3	,,	,,	31·4
	66·85	4	66·99	67·3		10	,,	,,	39·3
			65·33			1	,,	,,	50·6
	4·52	4	64·60	64·9		6	,,	,,	56·0
			62·70			1	,,	,,	69·2
			61·16	61·4		2n	,,	,,	80·0
			59·3			1n	,,	,,	93·2

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			3758·40			1	1·04	7·5	26599·6
			57·99	3758·2		5	,,	,,	26602·5
			57·10			1	,,	,,	08·8
			56·42	56·7		1	,,	,,	13·6
			54·95			2	,,	,,	24·0
			54·25			1n	,,	,,	29·0
	3751·79	3	51·85	52·0		12	,,	,,	46·2
			50·87	51·0		3	,,	,,	53·0
			48·07			1n	,,	,,	72·9
			46·18	46·4		11	,,	,,	86·4
			45·16			1	,,	,,	93·6
			44·7			1n	,,	,,	96·9
			44·2			1n	,,	,,	26700·5
			42·4			2b	,,	,,	13·3
			42·0			1b	,,	,,	16·2
			40·50			1	,,	,,	26·9
			39·95			1	,,	,,	30·8
			39·6	39·3		1	,,	,,	33·3
			38·32	38·3		4	,,	,,	42·5
	37·55	2	37·54	37·6		2	1·03	,,	48·0
			36·70			1	,,	,,	54·1
			35·75			1	,,	,,	60·9
			33·93			1	,,	,,	73·9
			33·48			1	,,	,,	77·2
			31·50	31·4		6	,,	,,	91·4
			30·61			1	,,	,,	97·8
			29·98*	29·7		4	,,	,,	26802·3
			28·83			1	,,	,,	10·6
			27·90	27·7		8	,,	7·6	17·2
			26·80	26·9		1	,,	,,	25·2
			24·94	24·8		1	,,	,,	38·6
			24·2	24·2		1n	,,	,,	43·9
			23·40			1	,,	,,	49·7
				22·8		1	,,	,,	54·0
			21·86			2	,,	,,	60·7
			19·45			1	,,	,,	78·1
			19·02	18·5		5	,,	,,	81·2
			17·94	17·5		1	,,	,,	89·0
			17·18			1	,,	,,	94·5
	16·23	1n	16·23	16·2		1	,,	,,	26901·4
	14·92	1n	14·99	14·8		8	,,	,,	10·6
	14·29	4	14·30	14·0		2	,,	,,	15·4
			13·13			1n	,,	,,	23·8
			12·15			2	,,	,,	31·0
			11·85			1n	,,	,,	33·1
			11·2			1n	,,	,,	37·9
			09·51	09·4		11	,,	,,	50·1
	06·80	3	06·79	06·6		5	,,	,,	69·6
			05·70			1	,,	,,	77·8
			05·58			1	,,	,,	78·7
			05·0			1b	,,	,,	82·9

* Titanium 3729·97.

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda+$	$\frac{1}{\lambda}-$	
			3703·71			1	1·03	7·6	26992·4
			03·0			1b	,,	,,	97·5
			02·05			1n	,,	,,	27004·5
			01·30			2	,,	,,	09·9
				3701·1†		2	,,	,,	11·4
			00·82	‡		1n	,,	,,	13·4
			3699·90	3699·5		1	,,	,,	20·2
	3698·32	3	98·41	98·4		11	,,	,,	31·3
3697·603	97·63	2	97·70	97·5		5	1·02	,,	36·6
96·430		1					,,	,,	45·5
			94·6			2n	,,	,,	58·9
			94·00	93·8		3n	,,	,,	63·3
			92·75			1	,,	,,	72·5
91·530		8					,,	,,	81·4
			87·22	87·4		1	,,	,,	27113·1
			84·1			1b	,,	,,	36·1
				83·6§		2	,,	7·7	39·7
			82·81			2	,,	,,	45·5
			82·32	82·2		2	,,	,,	49·1
80·674	80·53	4	80·54			1	,,	,,	61·9
			79·80			1	,,	,,	67·7
			79·10	79·0		7	,,	,,	72·9
			75·90			1	,,	,,	96·5
74·859	74·84	3	74·98	74·8		10	,,	,,	27203·7
			72·81	72·6		2	,,	,,	19·3
71·410	71·40	2	71·49	71·3		9	,,	,,	29·6
			69·2			1n	,,	,,	46·2
	68·55	1	68·69	68·6		6	,,	,,	50·5
			67·53	67·6		2	,,	,,	58·6
			67·20			2	,,	,,	61·1
			65·98			1	,,	,,	70·1
			65·51			1	,,	,,	73·6
			65·20			1	,,	,,	75·9
63·784	63·79	8	63·81	63·8		7	,,	,,	86·4
			62·32	62·2		6	,,	,,	97·4
			61·49	61·3		3	,,	,,	27303·6
			61·40			3	,,	,,	04·3
	61·33	3					,,	,,	04·8
			61·10			2	,,	,,	06·5
			58·7			1n	,,	,,	24·4
58·290		1n	58·5			1n	,,	,,	27·5
				57·4		1	1·01	,,	34·1
	57·00	2	57·01			1	,,	,,	37·1
			55·72	55·8		5	,,	,,	46·7
				55·1		1	,,	,,	51·3
				53.5		1	,,	,,	63·3
				52·2		1	,,	,,	73·1
			51·65	51·5		3	,,	,,	77·2
			50·90	50·7		6	,,	,,	82·8
			49·30			1	,,	,,	94·8
			48·55			1	,,	,,	27400·4

† Ru 3701·1. ‡ Rh 3701·1. § Pb 3683·6.

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			3647·08			1	1·01	7·7	27411·5
			45·04			1	,,	,,	26·8
			44·54	3644·4		2	,,	,,	30·6
			40·67			1	,,	,,	59·8
	3638·83	1	38·87			1	,,	7·8	73·4
3636·601	36·57	2	36·69	36·3		6	,,	,,	90·3
34·298	34·28	3	34·33	34·1		4	,,	,,	27507·6
			33·70	33·5		7	,,	,,	12·3
			32·52			1	,,	,,	21·3
			32·23			1	,,	,,	23·5
			31·64			1	,,	,,	28·0
30·169	30·20	2	30·30	30·1		6	,,	,,	38·7
			29·20			2	,,	,,	46·5
				28·8*		4	,,	,,	49·5
			27·7			1n	,,	,,	57·9
			26·6			1n	,,	,,	66·6
			25·57			1	,,	,,	74·1
24·005	24·02	6	24·10	23·8		6	,,	,,	85·7
			22·0			1b	,,	,,	27601·3
			21·65	21·5		2n	,,	,,	03·9
			20·08			1	,,	,,	15·9
			18·96			2	,,	,,	24·4
			18·61	18·3		2	,,	,,	27·1
			17·02			1	1·00	,,	39·3
			16·90			1	,,	,,	40·2
14·925	14·92	5	15·09	14·9		10	,,	,,	54·9
	13·84	2	13·88	13·6		2	,,	,,	63·4
13·247	13·26	4	13·30	13·1		7	,,	,,	68·0
			12·61	12·4		2	,,	,,	73·0
12·042	12·05	2	12·13	12·0		10	,,	,,	77·1
			09·8	09·8		1b	,,	,,	94·6
			08·47			1	,,	,,	27704·8
	07·50	2	07·60	07·3		7	,,	,,	11·8
			06·06			1	,,	,,	23·3
			05·6			1b	,,	,,	26·8
			04·92	05·0		1	,,	,,	32·1
			03·95			1n	,,	,,	39·5
			02·97			1	,,	,,	47·1
			02·57			1	,,	,,	50·2
01·331	01·37	7	01·40	01·2		7	,,	,,	59·4
			00·11	00·0		7	,,	,,	69·1
			3599·55	3599·4		2	,,	,,	73·4
			99·2			1n	,,	,,	76·9
			97·60	97·6		1n	,,	,,	88·5
			96·45			1n	,,	,,	97·4
			94·35			1n	,,	7·9	27813·5
			93·80			1	,	,,	17·9
			93·31	93·2		1	,,	,,	21·6
			91·87			1	,,	,,	32·7
				90·8		1	,,	,,	41·0
			88·96			2	,,	,,	55·3

* Ir 3628·8.

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda+$	$\frac{1}{\lambda}-$	
			3588·51	3588·3		3	1·00	7·9	27878·8
	3588·07	3	88·19	88·0		6	,,	,,	61·6
			87·12			1n	,,	,,	69·6
	86·40	3	86·42	86·3		6	,,	,,	75·1
			85·70			1	,,	,,	80·7
			82·30	82·0		3	,,	,,	27907·1
			81·36			1	,,	,,	14·4
			80·65	80·8		1	,,	,,	20·0
			80·11			1	,,	,,	24·2
			78·40	78·4		6	,,	,,	37·5
	77·68	2	77·74	77·7		3	0·99	,,	42·9
	76·95	5	77·10	76·9		10	,,	,,	48·3
	75·91	4	75·89	75·8		5	,,	,,	57·1
	73·24	2	73·30	73·1		4	,,	,,	77·7
3572·606	72·60	9	72·70	72·6		12	,,	,,	82·6
			70·25			1	,,	,,	28001·3
			69·50			1	,,	,,	07·2
			69·18			1	,,	,,	09·7
	69·00	2	69·03	69·0		3	,,	,,	10·0
			68·32	68·3		3	,,	,,	16·5
			67·46			1	,,	,,	23·2
	66·25	5	66·30	66·2		6	,,	,,	32·6
	65·50	2	65·61	65·5		6	,,	,,	38·2
			64·33	64·2		1	,,	,,	47·7
			63·9			1n	,,	,,	49·0
				63·1		1	,,	,,	55·0
			62·66			1	,,	,,	61·0
			61·81	61·8		2	,,	,,	67·7
			61·37			1	,,	,,	71·2
				60·9		1	,,	,,	74·9
			60·37			1	,,	,,	79·1
	59·10	3	59·13	59·3		2	,,	,,	89·0
58·944		1					,,	,,	90·3
56·744	56·75	6	56·89	56·9		13	,,	,,	28107·3
			5·70	55·3		1	,,	,,	16·0
			54·31	54·3		6	,,	,,	27·0
			53·54	53·5		1	,,	,,	33·0
			52·91			1	,,	,,	38·0
52·093	52·12	5	52·20	52·2		10	,,	,,	44·2
	50·61	4	50·67	50·7		4	,,	8·0	55·9
	49·90	4	49·90	50·0		5n	,,	,,	61·8
			49·73			3	,,	,,	63·1
			48·60	48·8		3n	,,	,,	72·1
	47·82	8	47·90	48·2		3	,,	,,	78·0
			46·3			1b	,,	,,	90·4
	42·75	3	42·87	43·1		10	,,	,,	28218·2
			40·05			1	,,	,,	40·2
			39·17	39·6		3	,,	,,	47·2
			38·31			1	,,	,,	54·1
				37·5		2	0·98	,,	61·0
			37·11	37·1		3	,,	,,	63·7
			36·8			1n	,,	,,	66·1
			35·67	36·1		2	,,	,,	75·1

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda+$	$\frac{1}{\lambda}-$	
	3535·31	2	3535·30	3535·5		2	0·98	8·0	28278·1
	33·37	3	33·35	33·8		4	,,	,,	93·7
			31·00	31·5		6	,,	,,	28312·6
	30·37	2n	30·35	30·8		3	,,	,,	17·7
			30·17			2	,,	,,	19·2
			27·58	28·2		6	,,	,,	40·0
	25·95	2	26·00	26·5		6	,,	,,	52·9
			24·69			1	,,	,,	63·3
			24·38			1	,,	,,	65·8
			23·78			1	,,	,,	70·6
			23·20			1	,,	,,	75·3
			22·35			1	,,	,,	82·1
			21·01	21·6		4	,,	,,	92·9
			20·45	20·5		5	,,	,,	97·4
3519·736	19·75	7	19·80			3	,,	,,	28403·0
			18·9			1n	,,	,,	10·0
			18·4			1n	,,	,,	14·0
			17·56			1	,,	,,	20·8
			14·79	14·4		3	,,	,,	43·2
			12·81			2	,,	,,	59·2
			12·50			1	,,	,,	61·7
			11·70	11·7		2	,,	,,	68·2
	10·60	2	10·61	10·9		4	,,	,,	77·1
	09·49	3	09·48	10·0		3	,,	8·1	86·1
				08·7		3	,,	,,	92·5
			07·80			3	,,	,,	99·8
				07·3		3	,,	,,	28503·9
			06·66	06·9		2	,,	,,	09·1
			06·23			2	,,	,,	12·6
05·813	05·83	4	05·88			4	,,	,,	15·7
05·582	05·66	2	05·67			5	,,	,,	17·4
			03·3	03·4		1n	,,	,,	36·0
			02·2	02·2		1n	,,	,,	45·4
	01·65	1	01·67	01·9		1	,,	,,	49·8
	01·53	1	01·50			1	,,	,,	51·0
			00·31			3	,,	,,	60·8
3499·727	3499·74	1	3499·78			4	,,	,,	65·4
			98·00			8	0·97	,,	79·7
			97·21			1	,,	,,	86·1
96·343	96·38	9	96·40			20	,,	,,	93·0
			94·3			1b	,,	,,	28609·9
			93·46			1	,,	,,	16·8
			92·8			1n	,,	,,	22·2
			87·1			1n	,,	,,	69·0
			85·48			3	,,	,,	82·4
	84·98 Cy	1	84·8			1n	,,	,,	86·5
83·679	83·68	3r	83·70			7	,,	,,	97·1
	83·16	2	83·17			1	,,	,,	28701·4
82·949	82·95	3	82·96			1	,,	,,	03·2
81·300	81·30	4r	81·36			10	,,	,,	16·6
	80·55	2	80·59			3	,,	,,	22·8
	79·54	4r	79·58			10	,,	,,	31·2
	79·17	2	79·19			3	,,	,,	34·3

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
3478·929	3478·94	3					0·97	8·1	28736·2
	78·64	1	3478·68			2	,,	,,	38·6
78·455	78·45	2	78·45			2	,,	,,	40·3
			77·8			1n	,,	,,	45·7
			76·1			1n	,,	,,	59·8
			75·60			1	,,	,,	63·9
	73·05	1	73·02			1	,,	,,	85·1
			72·53			1	,,	,,	89·4
71·329	71·33	4	71·31			4	,,	,,	99·4
	70·10	1	70·10			3	,,	8·2	28809·4
	69·25	1	69·18			1	,,	,,	16·8
			66·6			1n	,,	,,	38·5
	65·76	1	65·76			1	,,	,,	45·5
			65·3			1b	,,	,,	49·3
63·166	63·16	3	63·23			12	,,	,,	67·0
	61·80*	1					,,	,,	78·5
61·244	61·25	3	61·22			2	,,	,,	83·2
			60·10			3	,,	,,	91·7
59·083	59·08	2	59·10			5	,,	,,	28901·2
57·715	57·71	3	57·75			6	0·96	,,	12·6
57·340	57·34	2	57·30			1	,,	,,	15·9
56·056	56·06	3	56·02			2	,,	,,	26·7
	54·71	1	54·71			3	,,	,,	37·8
	53·67†	1					,,	,,	46·5
	50·07	1	50·03			1	,,	,,	76·9
47·514	47·50	4	47·45			3	,,	,,	98·5
46·770	46·75	3	46·71			2	,,	,,	29004·7
	43·72	1	43·69			3	,,	,,	30·3
			42·72			1	,,	,,	38·6
			41·8			1n	,,	,,	46·4
			41·12			1	,,	,,	52·1
	40·77	2	40·70			1	,,	,,	55·3
	40·59	2	40·54			2	,,	,,	56·8
38·381	38·41	7	38·39			15	,,	,,	75·2
37·291	37·27	3	37·30			4	,,	,,	84·6
			34·9			1b	,,	,,	29104·7
	34·05	1	34·08			4	,,	,,	11·8
	32·56	1	32·59			4	,,	8·3	24·3
	31·74	1	31·71			3	,,	,,	31·6
30·683	30·70	4	30·73			10	,,	,,	40·3
	30·46	1					,,	,,	42·3
			27·23			2	,,	,,	69·8
24·978	24·95	2	25·02			3	,,	,,	89·0
			24·0			2b	,,	,,	97·3
			21·6			1n	,,	,,	29217·8
			21·05			1	,,	,,	22·5
19·813	19·78	2	19·76			1	,,	,,	33·3
	19·24	1	19·22			3	,,	,,	38·0
			16·80			1	0·95	,,	59·5
	14·89	2	14·87			6	,,	,,	75·5
14·816	14·82	2					,,	,,	75·8

* Ni 3461·80. † Co 3453·67.

ZIRCONIUM—*continued.*

Arc Spectrum: Wave-length: Rowland and Harrison	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Wave-length: Demarçay	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
	3413·50	1	3413·55			3	0·95	8·3	29286·9
			12·0			1b	,,	,,	29300·0
3410·405	10·41	5	10·44			8	,,	,,	13·6
10·366							,,	,,	14·1
			08·90			1	,,	,,	26·0
08·235	08·20	4	08·23			5	,,	,,	32·5
07·627		1n					,,	,,	37·7
04·987	04·98	4	05·03			6	,,	,,	60·3
03·840	03·83	2	03·89			4	,,	,,	70·2
03·011	03·02	3	03·10			4	,,	,,	77·2
			02·68			1	,,	,,	80·3
	01·95	1	01·94			1	,,	,,	86·6
	3399·94	1	3399·95			2	,,	,,	29403·9
	99·50	3	99·51			4	,,	,,	07·7
3398·997		7					,,	,,	12·1
	98·08	1	98·10			2	,,	,,	20·0
	96·78	1	96·71			3	,,	,,	31·6
96·468	96·48	4	96·51			3	,,	,,	33·9
	94·70	1	94·79			2	,,	8·4	48·9
94·389		1					,,	,,	52·0
93·268	93·26	5	93·30			4	,,	,,	61·6
92·378	92·14	10	92·20			15	,,	,,	70·6
			89·95			1	,,	,,	90·6
88·371	88·45	6	88·49			5	,,	,,	29504·3
88·802	88·03	5	88·07			5	,,	,,	07·2
	85·95	1					,,	,,	25·4
			85·40			1	,,	,,	30·2
			84·8			1b	,,	,,	35·4
	83·06	1					,,	,,	50·6
80·060	80·10	1	80·07			1	,,	,,	76·7
	78·47	1	78·47			3	,,	,,	90·8
77·585	77·57	3	77·61			3	0·94	,,	98·5
76·395	76·42	3	76·42			3	,,	,,	29608·8
	74·87	3	74·89			5	,,	,,	22·3
	73·57	2	73·61			4	,,	,,	33·6
			73·05			1	,,	,,	38·4
	70·85	2	70·73			1	,,	,,	58·2
	69·44	1	69·42			2	,,	,,	70·2
	68·80	1					,,	,,	79·8
	67·98	2	68·01			3	,,	,,	83·6
	63·99	2	64·00			3	,,	,,	29718·2
	62·87	1	62·77			3	,,	,,	28·5
			62·1			1n	,,	,,	36·9
			61·35			1n	,,	,,	41·5
	60·64	2	60·61			1	,,	8·5	47·9
	60·14	2	60·20			4	,,	,,	51·9
	57·43	3	57·48			4	,,	,,	76·0
	56·24	4	56·28			4	,,	,,	86·6
	54·55	2	54·59			3	,,	,,	29801·6
53·783	53·80	2	53·80			1	,,	,,	08·5
			53·3			1b	,,	,,	12·8
			52·21			1	,,	,,	22·6
			51·4			1b	,,	,,	29·8

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		λ+	$\frac{1}{\lambda}$ −	
			3350·75			1b	0·94	8·5	29835·6
3344·917	3344·95	5	45·00			4	,,	,,	87·3
			44·00			2	,,	,,	95·8
40·614	40·72	6	40·80			6	,,	,,	29925·3
38·545	38·55	5	38·61			4	0·93	,,	44·5
	38·07	1	38·07			2	,,	,,	48·9
34·744	34·75	5	34·81			4	,,	,,	78·6
34·382	34·40	5	34·49			4	,,	,,	81·7
	33·70	1	33·75			1	,,	,,	88·0
	32·90	1	32·88			1	,,	,,	95·5
			32·08			1	,,	,,	30002·8
			29·0			1b	,,	,,	30·5
			27·85			1	,,	,,	40·9
26·544		1	27·05			5	,,	,,	51·1
	25·95	2					,,	,,	58·1
	25·59	1	24·30			1	,,	,,	61·3
							,,	8·6	72·9
23·114	23·16	5	23·21*			4	,,	,,	83·1
	22·47	1	21·51			2n	,,	,,	89·3
			21·0			1b	,,	,,	30102·8
19·148	19·18	5	19·19			3	,,	,,	19·4
18·642	18·67	3	18·70			3	,,	,,	23·9
16·325	16·35	1	16·35			1	,,	,,	45·1
14·615	14·65	5	14·70*			4	,,	,,	60·4
13·832	13·85	4	13·89			3	,,	,,	67·7
			13·02			1	,,	,,	75·3
11·482	11·53	2	11·53			3	,,	,,	89·1
10·024	10·07	2	10·10			3	,,	,,	30202·3
06·411	06·50	6	06·48			6	,,	,,	35·2
	05·32	4	05·33			4	,,	,,	45·6
	02·81	1	02·89			3r	,,	,,	68·3
	3296·55	1	3296·59			3	0·92	,,	30326·0
			95·20			1	,,	,,	38·6
3288·935	88·82	4	88·99			3	,,	8·7	96·5
			88·52			1	,,	,,	30400·1
	87·40	1	87·46			2	,,	,,	10·2
86·025	86·03	2	86·01			4	,,	,,	23·2
84·827	84·85	7	84·89			4	,,	,,	33·9
82·969	82·98†	2	83·09			4	,,	,,	51·1
	82·89	1					,,	,,	52·3
	81·85	1	81·5			1b	,,	,,	61·9
			80·92			2	,,	,,	70·5
80·600		1n					,,	,,	73·5
79·399	79·42	7	79·45			5	,,	,,	84·5
			79·03			3	,,	,,	88·1
			76·55			1	,,	,,	30511·1
			75·80			1	,,	,,	18·2
	75·30	1	75·28			1	,,	,,	22·9
			74·13			1	,,	,,	35·4
73·168	73·23	6	73·22			8	,,	,,	42·7
72·333	72·38	5	72·39			4	,,	,,	50·2

* Ti 3323·10, 3314·60. † Ni 3282·96.

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		λ+	$\frac{1}{\lambda}$ −	
	3271·27	2	3271·30			3	0·92	8·7	30560·3
3269·788	69·81	5	69·81			1	,,	,,	74·2
64·945	64·98	3	64·96			2	,,	,,	30619·6
60·240	60·25	3	60·24			1	,,	,,	63·9
			59·4			1b	0·91	,,	71·8
			57·8			1b	,,	,,	86·9
			56·67			1	,,	,,	97·5
			56·11			1	,,	,,	30702·8
			55·4			1n	,,	,,	09·5
	54·40	1	54·42			1	,,	,,	18·8
			53·81			1	,,	,,	24·5
50·563	50·55	5	50·62			4	,,	8·8	54·9
47·672		1	47·67			2	,,	,,	82·4
44·108	44·13	1	44·10			1	,,	,,	30816·3
	42·29	1	42·32			3	,,	,,	33·4
41·171	41·18	5	41·26			4	,,	,,	43·9
			37·66			1	,,	,,	77·7
			36·75			2	,,	,,	86·4
		1	36·26			1	,,	,,	91·1
35·874							,,	,,	94·8
	34·94	1					,,	,,	30903·7
34·240	34·26	5	34·24			2	,,	,,	10·3
	33·27	1					,,	,,	19·6
	31·85	4	31·89			4	,,	,,	33·0
			30·0			1b	,,	,,	51·0
28·922	28·95	5	29·00			4	,,	,,	60·9
			24·04			1	,,	,,	31008·2
	22·65	1					,,	,,	21·5
			22·19			3	,,	,,	26·0
			20·80			1	0·90	,,	39·4
			18·84			1.	,,	,,	58·3
14·306	14·31	5	14·40			4	,,	8·9	31101·7
12·962	12·96	2	13·01			2	,,	,,	14·9
	12·68	1					,,	,,	17·8
12·123	12·14	4	12·17			2	,,	,,	22·9
			11·10			1	,,	,,	33·1
08·432	08·42	2	08·42			1	,,	,,	59·0
05·016	05·01	2	05·05			1	,,	,,	92·1
04·473		3	04·50			1	,,	,,	97·3
			00·79			1	,,	,,	31233·4
			3199·55			1n	,,	,,	45·5
			97·2			1n	,,	,,	68·5
3196·832		1	96·9			1n	,,	,,	72·9
94·536		1					,,	,,	94·4
			94·27			1	,,	,,	97·1
			93·18			1	,,	,,	31307·8
92·012	3192·04	5	92·11			3	,,	,,	18·9
91·328	91·35	5	91·31			1	,,	,,	26·0
			84·2			1b	,,	,,	96·2
82·953	83·01	7	83·08			5	,,	,,	31407·8
82·038	82·10	4	82·15			3	,,	,,	16·9
	81·69	2	81·79			3	0·89	,,	20·4
81·171	[illegible]	8	81·17			1	,,	,,	26·0

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
3178·193	3178·18	4	3178·30			3	0·89	9·0	31455·1
			77·00			1	,,	,,	67·2
			75·8			1b	,,	,,	79·1
			74·9			1b	,,	,,	88·1
			72·3			1b	,,	,,	31513·9
66·837		1	66·79			1	,,	,,	68·5
66·375	66·40	4	66·48			2	,,	,,	72·4
66·064	66·10	6	66·17			3	,,	,,	75·4
65·558	65·60	4	65·68			2	,,	,,	80·4
64·411	64·45	7	64·54			3	,,	,,	91·9
			61·12			1r	,,	,,	31625·4
			59·26			1	,,	,,	44·0
57·932	57·95	5	57·94			1	,,	,,	57·2
57·096	57·13	5	57·19			2	,,	,,	65·2
55·780	55·80	5	55·90			3	,,	,,	78·4
49·925		3	49·98			1	,,	,,	31737·4
			49·4			1b	,,	,,	43·0
	48·92	2					,,	,,	47·9
	39·94	3	39·96			1	0·88	9·1	31838·5
38·764	38·81	7	38·88			4	,,	,,	50·0
37·072	37·09	4	37·08			1	,,	,,	67·6
	34·85		34·85			1	,,	,,	90·3
33·584	33·62	8	33·70			4	,,	,,	31902·7
33·324									05·9
32·166	32·21	5	32·22			1	,,	,,	17·3
	31·25	3	31·23			1	,,	,,	27·1
			30·75			1n	,,	,,	32·1
	30·20	1					,,	,,	37·7
29·854	29·90	7	29·96			4	,,	,,	40·7
29·275	29·33	7	29·38			4	,,	,,	46·6
	28·95	1	28·96			1	,,	,,	50·5
26·010	26·07	7	26·10			3	,,	,,	80·0
25·308	25·35	3	25·33			2	,,	,,	87·5
	22·12	1					,,	,,	32020·4
20·851	20·90	6	20·90			1	,,	,,	33·1
19·320		1					,,	,,	49·2
			16·8			1b	,,	,,	75·1
	15·85	1	15·86			1	,,	,,	84·8
			14·15			1n	,,	9·2	32102·3
	13·65	1					,,	,,	07·4
	11·30	1					,,	,,	31·7
10·971	11·00	6	11·02			1	,,	,,	35·8
10·645	[illegible]	1					,,	,,	37·4
09·444	09·25	1n	09·27			1	,,	,,	52·1
	08·50	2					,,	,,	60·7
06·674	06·72	7	06·79			4	,,	,,	79·0
	3099·81	1					,,	,,	32250·8
3099·324	99·39	7	3099·42			3	0·87	,,	55·3
	95·95	2					,,	,,	91·1
95·435		1					,,	,,	96·4
95·174	95·22	6	95·29			3	,,	,,	98·6
94·908	94·94	2					,,	,,	32301·7
	93·46	1					,,	,,	17·1

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		λ+	$\frac{1}{\lambda}$ −	
	3092·41	1					0·87	9·2	32328·0
	90·57	2					,,	,,	47·3
	89·14	1					,,	,,	62·3
	86·57	1	3086·57			1n	,,	,,	89·2
3085·461	85·49	2	85·5			1b	,,	,,	32400·1
			75·72			1	,,	9·3	32503·4
	73·05	1					,,	,,	31·7
72·238		1n					,,	,,	40·2
	68·91	1					,,	,,	75·0
			68·2			1b	,,	,,	83·1
65·313	65·34	3	65·34			1	,,	,,	32613·6
64·746	64·85	3	64·78			1	,,	,,	19·3
	63·74	1	63·8			1b	,,	,,	30·5
61·449	61·46	3	61·49			1	0·86	,,	54·8
60·218	60·24	4	60·24			1	,,	,,	68·3
	57·34	2	57·37			1	,,	,,	99·7
	57·15	1					,,	,,	32700·9
54·927	54·98	7	55·00			4	,,	,,	24·3
	52·95	1					,,	9·4	45·8
	52·16	1					,,	,,	54·3
	50·91	1					,,	,,	67·7
	50·50	1					,,	,,	72·1
	49·45	2					,,	,,	83·4
	48·94	1					,,	,,	88·9
	48·51	1	48·45			1n	,,	,,	93·8
	48·38	1					,,	,,	94·9
	45·95	2					,,	,,	32821·1
	44·23	1	44·3			1n	,,	,,	39·6
	43·37	1					,,	,,	48·9
	36·60	3					,,	,,	32922·3
	36·51	3	36·57			3	,,	,,	23·1
	31·04	3	31·04			2	,,	,,	32·6
	29·65	5	29·63			1	,,	,,	97·8
	28·17	3	28·18			3	,,	,,	33013·8
	27·75	1					,,	,,	18·4
			26·3			1b	,,	,,	34·0
	25·73	1	25·87			1	,,	,,	39·7
	25·29	1	25·25			1n	,,	9·5	45·4
			24·85			1n	,,	,,	50·0
			21·3			1b	0·85	,,	89·0
	20·74	2					,,	,,	95·0
	20·59	3	20·53			2	,,	,,	96·9
	19·96	3	19·96			1	,,	,,	33103·5
	18·40	1n	18·6			1b	,,	,,	20·6
	16·90	1n					,,	,,	37·1
	14·56	1					,,	,,	62·8
	13·45	2	13·44			1	,,	,,	75·1
	13·01	1					,,	,,	79·9
	11·90	6	11·88			1	,,	,,	92·2
	10·01	1				1	,,	,,	33213·0
	09·71	1					,,	,,	16·3
			08·24			1	,,	,,	32·5
	05·62	2	05·6			1b	,,	,,	61·5

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	3005·50	2					0·85	9·5	33262·8
	03·88	3	3003·88			2	,,	,,	80·8
			00·8			1b	,,	,,	33314·0
	2999·66	1					,,	,,	27·6
	98·60	1	2998·6			1b	,,	,,	39·4
	98·46	1					,,	,,	41·0
	91·55	1	91·52			1n	,,	9·6	33418·0
	90·26	1					,,	,,	32·3
			89·0			1n	,,	,,	46·0
	87·87	1n	87·93			1	,,	,,	58·7
	85·52	4	85·53			1	,,	,,	85·5
	81·15	3	81·18			2	0·84	,,	33534·3
	80·97	1					,,	,,	36·5
	79·30	3	79·35			2	,,	,,	55·0
	78·18	3	78·21			2	,,	,,	67·8
	76·73	2	76·76			2	,,	,,	84·1
	76·00	1	76·00			1	,,	,,	92·5
	73·80	1					,,	,,	33617·4
	73·00	1					,,	,,	26·5
	69·76	3	69·77			3	,,	9·7	63·0
	69·31	2					,,	,,	68·2
	69·08	3	69·10			3	,,	,,	70·6
	64·99	1					,,	,,	33717·2
	64·68	1	64·7			1n	,,	,,	20·7
	62·82	3	62·81			2	,,	,,	42·0
	61·00	3					,,	,,	62·7
	55·90	3	55·92			3	,,	,,	33820·8
	54·33	1					,,	,,	38·9
	53·46	1					,,	,,	48·9
	52·36	2	52·40			1	,,	,,	61·3
	51·60	3	51·66			2	,,	,,	69·9
	50·80	1					,,	,,	79·4
	49·07	3	49·12			3	,,	,,	99·0
	45·56	1	45·56			1	,,	9·8	33939·6
	40·85	1					,,	,,	94·0
	37·85	1	37·88			1	0·83	,,	34028·7
	36·41	3	36·42			1	,,	,,	45·3
	34·71	3	34·73			1	,,	,,	65·0
			31·25			1n	,,	,,	34105·3
	29·70	1					,,	,,	23·4
	27·10	3	27·15			4	,,	,,	53·4
	25·74	1	25·7			1n	,,	,,	69·6
	24·75	1	24·75			1	,,	,,	81·1
	23·99	1					,,	,,	34200·0
	18·37	3	18·39			3	,,	9·9	55·9
	16·74	2	16·78			1	,,	,,	74·8
	16·60	1					,,	,,	76·7
	16·33	1					,,	,,	79·9
	16·10	3	16·12			3	,,	,,	82·5
	10·36	1	10·40			1n	,,	,,	34350·0
			08·05			1n	,,	,,	77·4
	07·51	1	07·50			1	,,	,,	83·8
	05·35	2	05·32			2	,,	,,	34409·5

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	2904·90	1					0·83	9·9	34414·7
	04·54	1					,,	,,	18·9
	04·42	1					,,	,,	20·4
	03·67	1	2903·75			2n	0·82	,,	28·8
	02·40	1	02·40			1	,,	,,	44·3
	01·95	1	01·97			1	,,	,,	49·6
	01·75	1	10·74			1	,,	,,	52·1
	2898·84	2	2898·85			1	,,	,,	86·6
	98·40	1					,,	,,	91·9
			95·45			1n	,,	10·0	34520·9
	92·39	2	92·0			1b	,,	,,	63·5
	89·53	1	89·54			1	,,	,,	97·6
	88·15	1	88·16			1	,,	,,	34614·2
			86·8			1n	,,	,,	30·4
	84·55	1					,,	,,	54·4
			84·2			2b	,,	,,	61·7
	83·92	1	83·93			1	,,	,,	65·0
	82·22	1	82·23			1	,,	,,	85·4
	80·95	1					,,	,,	34700·8
	77·65	2	77·69			1	,,	,,	40·3
			76·60			1	,,	,,	53·3
	76·10	3					,,	,,	59·3
			74·3			1b	,,	,,	81·1
	72·65	1	72·68			1	,,	10·1	34800·8
	69·93	3	69·94			3	,,	,,	33·9
			69·26			2	,,	,,	42·1
	66·50	1					,,	,,	75·6
	65·73	2	65·77			1	,,	,,	84·8
	65·21	1	65·28			1	,,	,,	90·9
	61·82	1	61·85			1	0·81	,,	34932·5
	60·97	1	61·1			1n	,,	,,	43·1
			59·7			1b	,,	,,	58·6
	58·10	1					,,	,,	78·2
	56·18	1	56·21			1	,,	,,	35001·5
	54·55	1	54·55			1	,,	,,	21·7
			53·8			1b	,,	,,	30·9
	52·10	2	52·11			3	,,	,,	51·7
			51·40			1n	,,	,,	60·4
			50·75			2n	,,	,,	68·4
			49·30			1n	,,	,,	86·2
	48·62	2	48·62			1	,,	,,	94·7
	48·27	2	48·28			2	,,	10·2	98·8
			46·27			1	,,	,,	35123·5
	44·69	3	44·75			4	,,	,,	42·6
	43·63	2	43·64			2	,,	,,	56·1
	39·46	1	39·41			2	,,	,,	35208·1
	38·15	1	38·13			1	,,	,,	24·1
	37·39	3	37·32			1	,,	,,	33·9
	36·61	1					,,	,,	43·2
			36·28			2	,,	,,	47·2
	34·54	1	34·48			1	,,	,,	69·3
	34·05	1	34·01			2	,,	,,	75·2
	29·94	1					,,	,,	35326·3

ZIRCONIUM—*continued.*

Arc Spectrum: Wave-length: Rowland and Harrison	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Wave-length: Demarçay	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
			2828·00			1n	0·81	10·2	35350·5
	2827·65	1	27·64			1	,,	,,	54·9
	25·69	3	25·65			3	,,	,,	79·6
			24·44			1	0·80	,,	95·0
			22·79			1	,,	10·3	35415·6
	21·69	1					,,	,,	28·2
	20·34	1	20·32			1	,,	,,	46·5
	19·66	1	19·4			1b	,,	,,	55·0
	18·85	3	18·81			3	,,	,,	65·4
	15·62	1					,,	,,	35505·9
	15·02	3	15·00			1	,,	,,	13·5
	11·05	2	11·01			3	,,	,,	63·8
			09·53			1	,,	,,	82·8
	08·28	1	08·25			1	,,	,,	98·9
			08·0			1b	,,	,,	35602·2
			07·23			1	,,	,,	12·0
	06·90	1	06·80			2n	,,	,,	16·8
	2799·25	1	2799·27			2	,,	,,	23·4
			98·85			1n	,,	,,	28·7
	97·01	2	97·02			2	,,	,,	42·1
	95·20	1					,,	,,	65·3
	93·51	1					,,	,,	87·0
	92·15	1					,,	,,	35804·4
	90·26	1	90·27			1	,,	10·4	29·5
			89·85			1	,,	,,	33·8
			89·6			1n	,,	,,	37·0
	86·98	1	87·1			2b	,,	,,	70·7
			86·00			1n	,,	,,	83·3
	83·67	1	83·68			1	0·79	,,	35913·3
			77·1			1b	,,	,,	98·4
			76·7			1b	,,	,,	36003·6
			75·38			1	,,	10·5	20·6
	74·27	2	74·28			3	,,	,,	35·0
			73·47			1	,,	,,	45·4
	68·86	2	68·88			3	,,	,,	36105·3
	63·12	1					,,	,,	80·5
	62·01	1	62·01			1	,,	,,	95·0
			60·2			1b	,,	,,	36218·8
	59·59	1					,,	,,	26·8
	58·92	3	58·91			3	,,	,,	35·8
	54·33	1	54·30			1	,,	,,	96·2
			53·3			1b	,,	,,	36309·5
			52·67			1n	,,	,,	17·9
	52·32	3	52·32			3	,,	,,	22·5
	51·05	1	51·03			1	,,	10·6	39·3
			50·50			1n	,,	,,	46·4
			49·94			1n	,,	,,	53·8
			49·40			1n	,,	,,	61·0
			48·90			1n	,,	,,	67·6
			47·02			1	,,	,,	92·7
	45·97	3	45·99			3	,,	,,	36406·3
			44·55			1n	,,	,,	25·2
	42·65	3	42·70			3	,,	,,	50·1

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	2741·65	2	2741·61			2	0·78	10·6	36464·0
	40·60	1	40·60			2	,,	,,	77·8
	40·46	1	40·47			2	,,	,,	79·6
			39·8			1n	,,	,,	88·4
			38·84			1	,,	,,	36501·2
			38·46			1	,,	,,	06·3
	37·95	1					,,	,,	13·0
			35·91			3	,,	,,	40·3
	34·92	3	34·99			3	,,	,,	53·1
	32·80	3	32·80			3	,,	,,	81·9
			30·00			1	,,	,,	36619·4
			28·64			1	,,	,,	37·7
	27·14	1	27·01			1	,,	10·7	58·6
	26·60	3	26·61			4	,,	,,	64·9
	25·57	1	25·52			1	,,	,,	79·2
	22·69	3	22·71			1	,,	,,	36717·5
			21·48			2	,,	,,	34·0
	20·44	1	20·46			3	,,	,,	47·9
			20·14			3	,,	,,	52·1
	18·37	1					,,	,,	76·0
	17·60	1					,,	,,	86·8
			15·85			3	,,	,,	36810·2
	14·35	2	14·32			3	,,	,,	30·7
	12·51	2	12·50			3	,,	,,	55·6
	11·60	2	11·60			1	,,	,,	68·9
	09·43	1					,,	,,	97·4
			09·13			1	,,	,,	36901·5
	06·25″	1	06·48			1n	,,	,,	39·2
			04·80			1b	,,	,,	60·6
			03·40			1n	,,	,,	79·8
			01·2			1b	,,	10·8	37009·8
	00·22	3	00·29			4	,,	,,	22·7
	2699·71	2	2699·70			2	,,	,,	30·3
			98·47			3	0·77	,,	47·2
	95·55	1	95·53			2	,,	,,	87·5
	94·16	2	94·16			3	,,	,,	37106·5
	93·65	2	93·62			3	,,	,,	13·8
	93·02	1					,,	,,	22·5
	92·73	1	92·71			2	,,	,,	26·4
			92·11			2	,,	,,	34·8
			90·63			4	,,	,,	55·2
	89·55	1	89·56			2	,,	,,	70·1
	87·85	1					,,	,,	93·7
			86·42			4	,,	,,	37213·5
			83·46			1	,,	,,	54·5
			82·31			5	,,	,,	70·5
	81·86	1	81·88			1	,,	,,	76·6
	78·72	3	78·78			5	,,	10·9	37319·9
			75·6			1b	,,	,,	63·9
			71·06			2	,,	,,	37427·4
	70·09	1					,,	,,	41·0
	69·56	1	69·53			2	,,	,,	48·7
	67·90	2	67·89			2	,,	,,	72·8

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		λ+	$\frac{1}{\lambda}$−	
			2665·23			1	0·77	10·9	37509·3
			64·40			4	,,	,,	21·0
			62·58			1	,,	,,	46·6
			61·98			1	,,	,,	55·1
	2658·80	1					,,	,,	37600·0
			56·58			4	,,	,,	31·5
	50·48	1	50·45			2	0·76	11·0	37718·2
	47·91	1					,,	,,	54·6
			47·34			2	,,	,,	62·8
			43·90			5	,,	,,	37811·9
	43·51	1	43·46			1	,,	,,	17·9
			42·6			1b	,,	,,	30·5
			41·48			2	,,	,,	46·6
	39·19	2	39·17			3	,,	,,	79·6
			38·78			1	,,	,,	85·3
	35·54	1					,,	,,	37931·9
			34·39			2	,,	,,	48·4
	30·97	2	30·99			4	,,	11·1	97·6
	30·55	1					,,	,,	38003·8
			28·32			4	,,	,,	36·0
			27·04			1	,,	,,	54·6
	26·52	1	26·51			1	,,	,,	62·2
			22·85			1	,,	,,	38115·4
			21·34			2	,,	,,	37·3
			20·70			8	,,	,,	46·6
			19·29			1n	,,	,,	67·5
			18·48			1	,,	,,	79·0
			16·06			1n	,,	,,	38214·3
			15·65			1n	,,	,,	20·3
			13·70			1	,,	,,	48·8
	12·27	1					,,	,,	69·8
			11·99			1	,,	,,	74·2
	09·53	1	09·80			2	0·75	,,	38308·0
			08·72			1n	,,	11·2	21·8
			07·08			1	,,	,,	45·9
			06·43			1	,,	,,	55·5
			04·93			1n	,,	,,	77·5
			04·30			1n	,,	,,	86·9
			00·45			1n	,,	,,	38443·7
			2599·45			1	,,	,,	58·5
			93·78			5	,,	,,	38542·6
	2589·15	1	89·13			3	,,	,,	38611·6
	83·74	1					,,	11·3	92·9
	83·50	1	83·49			2	,,	,,	96·0
			74·03			1	,,	,,	38838·3
	71·52	3	71·50			8	,,	,,	76·4
	68·96	2	68·99			7	,,	,,	38914·7
	67·72	2	67·73			5	,,	11·4	33·6
	67·54	1					,,	,,	36·4
	67·19	1	67·18			2	,,	,,	41·8
			58·15			1n	0·74	,,	39079·3
			51·50			1	,,	,,	39181·2
	50·86	2	50·86			4	,,	,,	91·1

ZIRCONIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	2550·64	1					0·74	11·4	39194·1
	42·22	2	2542·21			4	,,	11·5	39324·4
	39·74	1					,,	,,	62·7
			35·28			1	,,	,,	39432·0
	32·57	1	32·60			3	,,	,,	73·8
	32·52	1					,,	,,	74·9
			22·03			1	,,	11·6	39639·0
			17·00			1	0·73	,,	39718·2
			13·15			1	,,	,,	79·1
			12·81			1	,,	,,	84·5
			12·20			1	,,	,,	94·1
			09·25			1	,,	11·7	39840·8
	04·07	1	04·10			1	,,	,,	39923·2
			2496·61			2	,,	,,	40042·6
			95·27			1	,,	,,	64·1
			94·17			1	,,	,,	81·8
			92·27			1	,,	11·8	40102·3
			87·94			3	,,	,,	82·1
			85·72			1	,,	,,	40218·0
			78·67C			4	,,	,,	40332·4
			69·30			1n	0·72	11·9	40485·4
			65·51			1	,,	,,	40547·6
			64·30			1	,,	,,	67·6
			60·61			1	,,	,,	40628·4
	2457·05	1	57·54			6	,,	12·0	84·0
	49·95	1	49·91			5	,,	,,	40805·5
			48·92			6	,,	,,	22·3
			47·30			1	,,	,,	49·4
			44·19			4	,,	,,	40901·4
	42·10	1	42·07			2	,,	12·1	36·5
			38·83			1n	,,	,,	91·2
			34·66			2	,,	,,	41061·4
			33·63			1	,,	,,	78·8
			26·48			1	,,	12·2	41199·7
			20·76			4	0·71	,,	41287·1
	19·51	1	19·51			3	,,	,,	41318·5
			17·78			1	,,	,,	48·0
			10·21			1	,,	12·3	41477·8
			06·93			1	,,	,,	41534·4
			06·80			3	,,	,,	36·6
			05·91			3	,,	,,	52·0
	05·61	1	05·51			1	,,	,,	58·1
			00·22			1	,,	,,	50·5
			2399·08			1	,,	,,	41670·3
			93·90			1	,,	12·4	41760·4
			93·4			1n	,,	,,	69·2
			92·78			2	,,	,,	80·0
			89·63			2n	,,	,,	41835·1
			89·43			2n	,,	,,	38·2
			89·26			1	,,	,,	58·2
			88·08			1	,,	,,	64·9
	2387·26	1	87·26			2	,,	,,	76·6
	84·25	1					,,	,,	41929·5

ZIRCONUIM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length			Intensity and Character			
Rowland and Harrison	Exner and Haschek		Exner and Haschek	Demarçay	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			2383·62			1	0·71	12·4	41940·6
			82·71			1	,,	12·5	56·5
			82·51			1	,,	,,	60·0
			82·15			1	,,	,,	66·4
			80·4			1n	,,	,,	42097·
	2374·54	1					,,	,,	42100·9
	73·75	1					,,	,,	14·9
	73·26	1					,,	,,	23·6
	73·04	1	73·02			2	0·70	,,	27·7
			70·27			1n	,,	,,	76·8
			63·97			1	,,	12·6	42289·1
			61·87			1	,,	,,	42326·7
			59·2			1b	,,	,,	75·
	57·52	1	57·50			4	,,	,,	42405·0
			53·29			1	,,	12·7	81·0
			51·77			2	,,	,,	42508·5
			51·28			1	,,	,,	17·3
			51·02			1	,,	,,	22·0
			47·50			1	,,	,,	85·8
			47·23			1	,,	,,	90·7
			42·45			1n	,,	,,	77·7
			36·58			1n	,,	12·8	42784·8
			31·6			1b	,,	,,	42876·
			30·44			3	,,	,,	97·5
			24·89			3	0·69	,,	42900·0
			24·60			1	,,	12·9	43015·2
			22·58			1	,,	,,	42·7
			22·00			1	,,	,,	53·4
			17·33			3	,,	,,	43140·2
			13·53			1	,,	13·0	43211·0
			08·18			2	,,	,,	43311·2
	03·18	1					,,	,,	43405·2
			01·6			1n	,,	,,	35·
			2296·96C			3	,,	13·1	43522·7
			95·59			3	,,	,,	48·7
	2294·18	1	94·14			3	,,	,,	75·9
	91·25	1	91·22			3	,,	,,	43631·5
			86·73			3	,,	13·2	43717·4
			80·43			1	,,	,,	43838·2
			77·27			1	0·68	,,	99·0
			76·5			1n	,,	,,	43914·
			27·88			1n	0·67	13·7	44972·0
			2163·81			3	0·66	14·2	46200·6
			38·70			1n	,,	14·4	46743·0

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K—Observed also by Kellner.
Ky—Observed also by Kayser.

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
5930·330			1				1·62	4·6	16857·9
5874·941			1n				1·60	,,	17016·8
74·200			1n				,,	,,	19·0
63·902			2				,,	,,	48·9
55·792			1				,,	,,	72·5
48·584			1n				1·59	,,	93·6
45·243			1n				,,	,,	17103·3
29·929			1n				,,	4·7	48·2
24·037			1				,,	,,	65·5
22·185			1				,,	,,	71·0
08·524			2				1·58	,,	17211·4
05·984			2				,,	,,	18·9
5795·785			4				,,	,,	52·1
91·539			4				,,	,,	61·9
89·438			6				,,	,,	68·1
69·545			5				1·57	,,	27·7
69·285			5				,,	,,	17328·5
62·044	5762·040		6				,,	,,	50·3
44·625	44·619		6				,,	,,	17402·9
	43·136		2r				,,	,,	07·4
40·871	40·862		6				1·56	,,	14·3
35·159	35·152		2n				,,	,,	31·6
	27·481		3				,,	,,	55·0
20·223	20·222		2n				,,	4·8	77·0
	14·736		2n				,,	,,	93·8
	14·230		3				,,	,,	95·4
	12·612		5				,,	,,	17500·3
	11·014		2n				,,	,,	05·2
03·530	03·470		1				1·55	,,	28·3
	02·765		2				,,	,,	30·5
	01·352		2n				,,	,,	34·9
	00·448		3n				,,	,,	37·7
	5699·584		3n				,,	,,	40·3
	96·400		6				,,	,,	50·1
	90·615		1n				,,	,,	68·0
	83·897		1n				,,	,,	88·8

Lanthanum—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	5682·446		1n				1·55	4·8	17593·3
5671·765	71·753		3				,,	,,	17626·4
	70·190		1n				,,	,,	31·3
	67·801		1n				,,	,,	38·1
	64·786		1n				1·54	,,	48·1
	61·587		1n				,,	,,	58·3
57·940	57·927		5				,,	,,	69·5
	56·786		2				,,	,,	73·1
	55·059		2r				,,	,,	94·1
	48·444		10				,,	,,	99·2
	39·491		6				,,	,,	17727·3
	32·213		6				,,	,,	50·2
	31·423		8				,,	,,	52·7
	13·074		1n				1·53	,,	17810·7
	10·765		1n				,,	,,	18·1
	5591·705		1				,,	4·9	78·7
5588·558	88·544 K		6				1·52	,,	88·8
	82·168		1n				,,	,,	17912·5
	78·218		1n				,,	,,	22·0
	70·586		2				,,	,,	46·5
68·674	68·674 K		6				,,	,,	52·8
	67·140		3				,,	,,	57·6
65·931	65·935 K		4				,,	,,	61·5
65·660	65·632		5				,,	,,	62·5
	62·760		1n				,,	,,	71·8
45·132	45·136		3				1·51	,,	18028·9
	41·472		7				,,	,,	40·8
35·889	35·889 K		5				,,	,,	58·0
	32·261		3				,,	,,	70·9
	30·095		4				,,	,,	78·0
	26·730		2n				,,	,,	89·0
	24·615		2n				,,	,,	95·9
17·562	17·563 K		4				,,	,,	18119·0
15·502	15·493		5				,,	,,	25·8
	07·550		1n				1·50	,,	52·0
	06·211 K		6				,,	,,	56·4
04·021	04·013 K		6				,,	5·0	63·5
02·878	02·861		3				,,	,,	67·3
02·465	02·449		3				,,	,,	68·7
01·559	01·545 K		9				,,	,,	75·0
	5498·907		2n				,,	,,	80·4
5493·656	93·654 K		4				,,	,,	97·8
91·277	91·252		3				,,	,,	18205·7
	87·014		1n				,,	,,	19·9
82·474	82·465 K		5				,,	,,	35·0
80·940	80·916		2n				,,	,,	40·1
75·450	75·358		5				1·49	,,	58·5
	67·113		4				,,	,,	86·2
64·574	64·568 K		4				,,	,,	94·7
58·887	58·876		2				,,	,,	18313·7
55·351	55·340 K		8r				,,	,,	25·2
	37·748		3				1·48	,,	81·6
	22·312		2				,,	,,	37·3

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	5415·873		3				1·48	5·0	18359·2
5381·168	5381·187 K		4				,,	,,	78·2
	80·214		1				,,	,,	81·5
77·265	77·290 K		3				,,	,,	91·7
	66·077		2				,,	5·1	18630·5
	59·911		1				1·46	,,	51·9
58·044	58·060		3n				,,	,,	58·4
40·836	40·879 K		3				,,	,,	18718·5
	23·745		2				1·45	,,	78·7
	20·335		1				,,	,,	80·7
	07·715		2				,,	,,	18835·4
	04·187		3				,,	,,	47·9
03·708	03·727 K		4				,,	,,	49·6
02·793	02·813 K		5				,,	5·2	52·7
02·135	02·159 K		6				,,	,,	55·1
5290·988	5291·010 K		4				,,	,,	94·8
	87·596		1n				1·44	,,	18907·0
	79·303		2				,,	,,	36·7
	76·586		3				,,	,,	46·4
71·337	71·359 K		4				,,	,,	65·3
59·539	59·549 K		3				,,	,,	19006·4
	58·019		1				,,	,,	13·4
	53·621		5				,,	,,	29·3
	40·981		3				1·43	,,	75·2
	39·716		2				,,	,,	79·8
	38·277		1n				,,	,,	85·1
34·435	34·445 K		5				,,	,,	99·0
12·014	26·362		2				,,	,,	19128·6
	12·037 K		8				1·42	,,	81·1
04·293	04·321		5				,,	5·3	19209·5
5188·371	5188·374 K		8				,,	,,	68·6
	84·063		4				,,	,,	84·6
83·664	83·584 K		7n				,,	,,	86·2
	79·275		2				,,	,,	19302·4
77·453	77·471 K		6				1·41	,,	09·2
	74·015		3				,,	,,	22·0
	73·065		2				,,	,,	25·6
	67·958		3				,,	,,	44·7
	64·197		1n C?				,,	,,	58·8
63·768	63·787 K		3				,,	,,	60·4
58·846	58·863 K		5				,,	,,	78·8
57·582	57·612 K		3				,,	,,	83·6
56·888	56·910 K		3				,,	,,	86·2
45·582	45·594 K		4				,,	,,	19428·8
	35·621		1n				1·40	,,	66·5
23·149	23·160 K		6				,,	,,	19513·9
	21·040		2				,,	,,	22·0
14·723	14·732 K		6				,,	5·4	46·0
	09·290		1n				,,	,,	66·4
06·395	06·414 K		4				,,	,,	77·8
	03·310		1n				,,	,,	89·7
	5096·799		1n				1·39	,,	19614·8
	90·733		1				,,	,,	38·1

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	5080·384		1n				1·39	5·4	19678·2
	79·546		1n				,,	,,	81·4
	79·119		1n				,,	,,	83·1
	72·295		1n				,,	,,	19709·4
	68·040		2				,,	,,	26·1
5063·097	63·070		2n				1·38	,,	45·5
56·628	56·628		3				,,	,,	70·6
50·734	50·737		3n				,,	,,	93·7
	48·182						,,	,,	19803·7
47·051	47·043		3n				,,	,,	08·2
	19·685		2n				1·37	5·5	19916·1
02·305	02·282		2n				,,	,,	85·4
01·979	01·960		2n				,,	,,	19986·5
4999·642	4999·641 K		8				,,	,,	95·9
	96·974		2				,,	,,	20006·6
	94·821		1n				,,	,,	15·2
	94·024		3				,,	,,	18·4
91·452	91·436 K		4				,,	,,	28·8
87·059	86·989 K		6				1·36	,,	46·9
	85·089		1n				,,	,,	54·3
	78·096		2				,,	,,	82·5
70·566	70·552 K		5				,,	,,	20112·9
	68·757		1n				,,	,,	20·2
	64·982		1				,,	,,	35·5
	56·230		1n				,,	,,	71·1
52·238	52·213		3				1·35	,,	87·4
49·947	49·940 K		5				,,	,,	96·8
	46·602		5				,,	,,	20210·4
	46·004		1				,,	,,	12·9
	35·773		2				,,	5·6	54·6
35·003	34·999 K		4				,,	,,	57·8
	25·553		1				,,	,,	96·7
21·979	21·952 K		7				,,	,,	20311·5
21·149	21·129 K		7				,,	,,	14·9
	16·780		1n				1·34	,,	32·9
	05·294		2				,,	,,	80·5
	02·037		3				,,	,,	94·1
00·096	00·085 K		7				,,	,,	20402·2
	4894·414		1n				,,	,,	25·9
	87·780		2n				,,	,,	53·8
	86·990		1n				,,	,,	56·9
	79·020		3				,,	,,	90·3
	70·734		2				1·33	,,	20525·2
	69·077		1n				,,	,,	31·8
4861·081	61·062 K		6				,,	5·7	65·9
	55·110		3				,,	,,	91·2
51·000	50·978		3n				,,	,,	20608·5
50·772	50·742		3n				,,	,,	09·6
	43·452		1n				,,	,,	40·7
40·203	40·183		4				1·32	,,	54·6
39·697	39·689		4				,,	,,	56·8
	30·682		2				,,	,,	95·3
	27·031		3				,,	,,	20710·9

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
4824·239	4824·220 K		7				1·32	5·7	20723·0
	17·333		2r				,,	,,	52·7
09·690			5				,,	,,	85·7
09·183	09·182 K		6				,,	,,	87·9
04·219	04·218 K		6				1·31	,,	20809·3
	00·426		3				,,	,,	25·8
	00·178		3				,,	,,	26·9
4796·862	4796·864		3n				,,	,,	41·2
	94·749		2n				,,	,,	50·4
	92·644		1n				,,	,,	59·6
	91·570		1				,,	,,	64·3
	80·734		1n				,,	5·8	20911·5
	80·082		3				,,	,,	14·3
	75·339		2				,,	,,	35·1
	70·629		5				,,	,,	55·8
67·073	67·085 K		6				,,	,,	71·4
	59·890		1n				1·30	,,	21003·1
	58·586		1n				,,	,,	08·8
	57·744		1n				,,	,,	12·6
	57·342		1n				,,	,,	14·3
	57·147		1n				,,	,,	15·2
	53·305		1n				,,	,,	32·2
	53·000		1n				,,	,,	33·5
	52·561		2				,,	,,	35·5
	50·593		5				,,	,,	44·2
48·911	48·897 K		6				,,	,,	51·7
43·273	43·255 K		9				,,	,,	76·7
	42·289		1n				,,	,,	81·1
	40·433		8				,,	,,	89·3
	39·961		3				,,	,,	91·4
	37·494		1n				,,	,,	21102·4
	33·978		3				,,	,,	18·0
	29·273		1n				1·29	,,	39·1
28·594	28·555 K		8				,,	,,	42·3
	24·565 K		5				,,	,,	60·2
	23·862		3				,,	,,	63·3
	20·827		1n				,,	,,	76·9
	20·081		8				,,	,,	80·3
	19·212		1n				,,	,,	84·2
	17·743		5				,,	,,	90·8
16·704							,,	,,	95·4
	16·594 K		5n						95·9
	15·631		1n				,,	,,	21200·3
	14·307		3				,,	,,	06·2
	13·081		8				,,	,,	11·7
	08·350		6				,,	,,	33·1
03·429	03·446 K		3				,,	5·9	55·1
	02·809		1n				,,	,,	58·0
4699·811	4699·796 K		2n				,,	,,	71·6
92·680	92·681 K		6	4692·67		3	,,	,,	21303·9
91·364	91·344 K		4				1·28	,,	09·9
88·824			1n				,,	,,	21·4
71·994	72·005 K	4672·00	3	72·00		3	,,	,,	28·2

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
4669·080	4669·097 K	4669·09	4	4669·10		3	1·28	5·9	21411·5
63·943	63·972 K	63·95	4	63·97		4	,,	,,	35·1
62·678	62·718 K	62·69	5	62·73		3	,,	,,	40·9
	60·907		2 C ?				,,	,,	49·1
55·667	55·714 K	55·67	6	55·71		6	,,	,,	73·2
	52·290 K	52·30	1				1·27	,,	88·9
	50·528		2				,,	,,	97·0
	48·844 K	48·78	3				,,	,,	21505·0
	47·673		2?	47·64		1	,,	,,	10·3
	46·542		1				,,	,,	15·4
	45·488 K	45·44	4	45·46		1	,,	,,	20·5
	36·603		1n	36·60		1n	,,	6·0	21661·5
20·054	20·059 K	20·02	3	20·06	4619·93	5	,,	,,	38·9
	15·240 Ky		2n				1·26	,,	61·3
13·557	13·576	13·53	5	13·60	13·54	4	,,	,,	69·2
05·951	05·962	05·95	3	05·99	06·00	2	,,	,,	21704·9
	05·268		1n				,,	,,	08·2
	04·410 Ky		1n				,,	,,	12·3
	02·213	02·20	2n				,,	,,	22·7
	4596·353		2				,,	,,	50·4
	81·383 Ky		2n				,,	,,	21821·5
4580·245	80·249 K	4580·25	5	4580·28	4580·37	3	1·25	,,	26·7
75·059	75·073 K	75·03	7	75·08	75·05	4	,,	,,	51·6
	71·144 Ky		2n				,,	,,	70·4
70·215	70·210 K	70·20	5	70·28	70·33	1	,,	,,	74·7
68·094	68·095 K	68·07	5	68·15	68·20	1n	,,	,,	84·8
	65·023 Ky	65·03	2				,,	,,	96·7
	59·467 K	59·46	4	59·51	59·57	2	,,	6·1	21926·1
58·660	58·650 K	58·62	7	58·66	58·72	4	,,	,,	30·2
	52·677 Ky	52·65	2n				,,	,,	59·1
50·956	50·948	50·95	2n				,,	,,	67·3
50·337	50·333 Ky		1n				,,	,,	70·3
49·679	49·682 K	49·67	5				,,	,,	73·5
	41·953	41·95	2				1·24	,,	22010·9
	30·755 Ky		1n				,,	,,	65·3
26·293	26·287 K	26·27	6	26·30	26·33	5	,,	,,	87·0
25·466	25·480 K	25·45	4	25·45	25·50	4	,,	,,	91·
22·544	22·550 K	22·55	7	22·61	22·62	8	,,	,,	22105·2
	01·761 K	01·73	2n				1·23	,,	22207·5
	00·411 K	00·36	4	00·4		1n	,,	,,	14·2
4499·223	4499·240 K	4499·20	2	4499·0		1n	,,	,,	20·0
	94·869 K	94·85	3				,,	6·2	41·4
	93·986 Ky		2				,,	,,	45·8
	93·308	93·26	3				,,	,,	49·2
	91·951 Ky	91·90	2 Y ?				,,	,,	56·2
	86·244 K	86·19	3				,,	,,	84·3
	79·990 Ky	79·96	2				,,	,,	22315·4
	74·716 Ky		3				,,	,,	41·6
	74·232 Ky		1n				,,	,,	44·0
	69·144 K	69·15	3				,,	,,	69·4
55·965	55·985 K	55·97	5	55·99	4456·07	2	1·22	,,	22435·4
	55·402 Ky		2n				,,	,,	38·5
	54·018 Ky		2n				,,	,,	45·4

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
4452·327	4452·338 K	4452·34	5				1·22	6·2	22453·9
	45·289 Ky		2				,,	,,	89·5
	44·369 K	44·37	2n				,,	,,	94·2
	44·119 Ky		1n				,,	,,	95·4
	42·839 K	42·80	3				,,	,,	22502·0
	40·902		1n				,,	,,	11·7
	37·086		2				,,	,,	31·1
	36·013 K	35·98	3n	4436·02	4436·11	1	,,	,,	36·5
35·392			1n		35·29	1	,,	,,	40·0
35·139			4				,,	,,	41·0
	33·121 Ky			33·15	33·22	2	,,	,,	51·0
32·296*			1n				,,	,,	55·5
30·075	30·064 K	30·09	12	30·11	30·26	8	1·21	6·3	66·4
27·741	27·750 K	27·73	6n	27·73	27·84	5	,,	,,	78·5
25·598			1n		25·73	1	,,	,,	89·2
24·082	24·080 K	24·06	4	24·08	24·18	1n	,,	,,	97·2
23·354			1n	23·37	23·42	1n	,,	,,	22600·8
19·329	19·328 K	19·27	3	19·30	19·42	2	,,	,,	21·6
	17·276		1n				,,	,,	32·1
	13·612		1n				,,	,,	50·9
11·379	11·382 Ky		2	11·45	11·55	1n	,,	,,	62·0
	03·195 Ky		3				,,	,,	22704·5
	02·825 K	02·82	3n				,,	,,	06·4
	4397·207		1n				,,	,,	35·1
	96·958		2n				,,	,,	36·7
	96·477 K Ky		2n				,,	,,	39·2
	93·778 K Ky		3				1·20	,,	53·2
	90·060 K	4390·05	3				,,	,,	72·5
4385·364	85·380 K Ky	85·34	4	4385·37	4385·45	3	,,	,,	96·7
83·624		83·62	4n	83·62	83·70	6	,,	,,	22805·7
	80·721 K	80·70	3				,,	,,	21·0
	79·421		1n				,,	,,	27·8
78·274	78·280 K	78·23	7n	78·24	78·04	3	,,	,,	34·1
	68·071		1n				,,	6·4	87·0
	64·845 K	64·80	6	64·85 Ce		3	,,	,,	22904·0
63·221	63·236 K Ky		3	63·25	63·33	1	,,	,,	12·2
	61·024		1				,,	,,	24·0
	60·649		2n Ti?				,,	,,	26·0
	58·085 Ky		2				,,	,,	39·5
	54·972 K	54·96	4				1·19	,,	55·9
54·565	54·570 K	54·56	7	54·54	54·64	6	,,	,,	58·0
	53·987		1				,,	,,	61·0
	40·898 K	40·90	3				,,	,,	23030·3
	40·105 Ky	40·09	1				,,	,,	34·5
	39·600 K	39·60	1n				,,	,,	37·2
				38·25		1n	,,	,,	44·4
				37·95		1n	,,	,,	46·0
35·134	35·135 K	35·13	5	35·18	35·27	5	,,	,,	60·8
33·934	33·933 K	33·98	15	33·97	34·08	12	,,	,,	67·1
	22·673 K	22·69	6			5	,,	,,	23127·4
18·825			1	22·19	18·90		1·18	,,	47·8
16·076	16·068 K	16·05	4	16·04	16·12	1	,,	,,	62·8
	11·902 K	11·90	2n				,,	,,	85·2

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda+$	$\frac{1}{\lambda}-$	
	4306·160 K	4306·16	3n				1·18	6·5	23216·1
4302·699	02·689 K		1n		4302·70	1	,,	,,	34·7
00·782	00·606 K	00·59	3	4300·59	00·62	3	,,	,,	45·6
4296·210	4296·213 K	4296·23	9	4296·21	4296·25	7r	,,	,,	69·7
87·128	87·137 K	87·10	8	87·09	87·12	15	,,	,,	23319·2
83·180			1			1	,,	,,	40·6
82·560			2		82·23		,,	,,	44·9
80·418	80·429 K	80·43	4	80·44	80·45	2	1·17	,,	55·6
75·797	75·802 K	75·81	4	75·80	75·82	4	,,	,,	80·9
					74·27	6	,,	,,	89·3
	69·662 K	69·64	6	69·65		10	,,	,,	23414·6
63·742	63·750 K	63·75	6	63·73	63·76	7	,,	,,	47·1
	62·510 K	62·51	3				,,	,,	53·8
	57·086 K	57·06	3				,,	,,	83·7
54·504			1				,,	,,	97·9
50·144	50·170 K	50·14	4	50·22	50·26	5	,,	6·6	23521·8
38·543	38·558 K	38·55	15	38·57	38·67	9	1·16	,,	86·2
31·107	31·122 K	31·11	4	31·10	31·26	5	,,	,,	23627·7
26·898			6		27·03	6	,,	,,	51·0
17·733	17·716 K	17·70	6	17·70	17·85	8	,,	,,	23702·8
15·683			2		15·85	2	,,	,,	13·9
04·218	04·195 K	04·18	5	04·20	04·26	4r	1·15	,,	79·1
	4196·710 K	4196·70	9	4196·74	4196·69	8	,,	6·7	23821·5
4194·654 } 94·369 }			1	94·57	94·53	2n r	,,	,,	33·8
92·501	92·507 K	92·49	6	92·50	92·47	6	,,	,,	45·5
	87·472 K	87·47	6	87·49		1	,,	,,	74·0
	77·634 K	77·65	3				,,	,,	23930·2
	72·467 K	72·48	3				,,	,,	59·9
	71·878 Ky		2n	71·88		1	,,	,,	63·3
	71·257	71·27	2				,,	,,	66·9
	63·461	63·50	3	63·50		1n	1·14	,,	24011·6
		61·44	2				,,	,,	23·5
	60·408 K		4	60·43		1	,,	,,	29·3
	57·653 K	57·68	1				,,	,,	44·3
54·120			2				,,	,,	65·8
	52·915 K	52·94	4	52·97	52·99	5	,,	,,	72·5
52·119	52·108 K	52·14	7	52·17	52·17	9	,,	,,	76·2
44·092		44·10	2n		44·07	1	,,	6·8	24124·0
41·872	41·871 K	41·92	9	41·90	41·95	8	,,	,,	36·5
	37·182 K	37·25	3		37·21	1	,,	,,	64·1
				33·5		1b	,,	,,	85·8
				32·7		1b	,,	,,	90·5
23·394	23·379 K	23·38	8	23·39	23·46	20r	1·13	,,	24245·0
	17·836 K	17·85	2n				,,	,,	77·8
				13·55		1b r	,,	,,	24303·1
	09·965 K	09·95	2				,,	,,	24·3
	09·641 K	09·65	1n				,,	,,	26·2
05·026	05·029 K	05·04	5	05·07	05·07	1	,,	,,	53·5
4099·678	4099·695 K	4099·70	6	4099·71	4099·73	7	,,	,,	85·0
95·278			3				,,	6·9	24411·5
90·920			4				,,	,,	37·5

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		λ+	1/λ −	
4090·547			1				1·13	6·9	24439·7
90·167			1				,,	,,	42·0
89·752	4089·767 K	4089·75	1	4089·76	4089·85	1	1·12	,,	44·3
86·848	86·866 K	86·86	10	86·90	86·97	15	,,	,,	61·6
	79·327 K	79·32	3	79·37	79·47	1	,,	,,	24506·5
78·890			1				,,	,,	09·6
77·856					77·96	2	,,	,,	15·5
77·503	77·487 K	77·50	10	77·51	77·58	12	,,	,,	17·8
76·845	76·853	76·87	3	76·89	76·97	2	,,	,,	21·6
67·519	67·547 K	67·56	6	67·52	67·61	6	,,	,,	77·9
65·715	65·734 K	65·75	3	65·75	65·82	1	,,	,,	88·8
64·922	64·939 K	64·95	4	64·94	64·99	1	,,	,,	93·7
63·735			1				,,	,,	24601·0
62·888			1n				,,	,,	06·1
60·459	60·476 K	60·50	5	60·52	60·51	1	,,	,,	20·6
59·633							,,	,,	25·9
			1n	58·30		1	,,	,,	34·0
50·217	50·241 K	50·24	5	50·25	50·27	7	1·11	7·0	82·9
45·962			10		46·01	3	,,	,,	24708·9
43·070	43·066 K	43·04	8	43·18	43·11	14r	,,	,,	26·5
	37·371 K	37·26	4	37·35	37·44	1	,,	,,	61·6
36·974			1n				,,	,,	64·0
	36·747 K		1n	36·74	36·78	2	,,	,,	65·4
35·878			1n	35·90		1	,,	,,	70·7
35·328			1n				,,	,,	74·1
31·847	31·848 K	31·85	7	31·86	31·88	13	,,	,,	95·5
26·013	26·038 K	26·01	5	26·03	26·08	3	,,	,,	24831·3
25·786			3				,,	,,	32·9
23·999			4				,,	,,	43·9
23·717	23·734 K	23·74	3	23·72	23·79	3	,,	,,	45·5
15·531	15·557 K	15·52	4	15·56	15·44	1	1·10	,,	96·4
13·535			1				,,	,,	24908·7
13·399			1				,,	,,	09·5
				07·82		1n	,,	,,	44·2
3995·903	3995·911 K	3995·90	10	3995·91		5r	,,	7·1	25018·5
				94·67		2n	,,	,,	26·3
88·669	88·668 K	88·69	10	88·66		30	,,	,,	63·9
				81·55		1n	,,	,,	25108·7
				79·3		1b	1·09	,,	23·0
				66·3 Nd?		1b	,,	,,	25205·3
				62·3		1b	,,	,,	30·8
	53·827	53·82	1				,,	,,	84·9
				53·2		1b	,,	7·2	88·8
49·256	49·240 K	49·27	12	49·22		50	,,	,,	25314·1
36·351	36·367 K	36·35	6	36·40		3	1·08	,,	96·9
	29·359 K	29·34	8	29·40		15	,,	,,	25442·2
	27·709 K	27·69	3	27·72		1	,,	,,	53·0
	21·684 K	21·69	8	21·71		10	,,	,,	92·0
16·053	16·186 K Ky	16·16	7	16·21		10	,,	,,	25528·1
	10·952 Ky		2				,,	,,	62·0
	02·717 K	02·72	2				,,	7·3	25616·9
	3898·743 K	3898·84	2				,,	,,	41·7

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	3895·801	3895·80	3				1·07	7·3	25661·4
3886·495	86·464 K	86·50	8	3886·51		15	,,	,,	25722·8
83·955			2				,,	,,	39·7
	71·764 K	71·80	8	71·89		20	,,	,,	25820·4
				64·67		3n r	,,	,,	68·1
				55·60		3	1·06	,,	25929·0
	49·167 K	49·14	7	49·20		10	,,	,,	72·3
	46·784						,,	,,	88·5
		46·15	2	46·16		3	,,	,,	92·7
	40·831 K	40·88	6	40·92		5	,,	,,	26028·4
		38·42	2				,,	,,	45·1
		35·24	2	35·29		5	,,	,,	66·5
		32·46	2n				,,	,,	85·6
				08·89		2	1·05	7·4	26248·0
				05·57		1	,,	,,	69·9
	3794·916 K	3794·90	10	3794·99		50	,,	,,	26343·5
3793·904			7				,,	,,	50·7
90·953	90·967 K	90·99	8	91·02		50	,,	,,	71·0
				87·31		2	,,	,,	96·6
	84·945	84·95	2	84·95		2	,,	,,	26413·0
				84·02		1	,,	,,	19·5
				83·67		1	,,	,,	22·0
	80·823 K	80·84	3	80·85		3n r	,,	,,	41·8
				80·70		2	,,	,,	42·7
				79·88		1	,,	,,	48·5
				73·8		2b	1·04	,,	91·1
				73·30		2	,,	7·5	94·5
				66·76		1	,,	,,	26540·5
59·217	59·227 K	59·22	8	59·33		20	,,	,,	93·6
				48·2		1b	,,	,,	26672·0
				36·6		2n r	1·03	,,	26754·8
	35·988		3	36·02		1	,,	,,	59·1
35·001			3				,,	,,	66·3
				31·6		1n	,,	,,	90·7
	25·199 K	25·21	2	25·24		3	,,	7·6	26836·5
	24·921						,,	,,	38·7
	15·675 K	15·66	6	15·67		4	,,	,,	26905·5
	15·014 K	15·02	5	15·03		3	,,	,,	10·1
	13·696 K	13·69	6	13·71		6	,,	,,	19·7
	05·968 K	05·94	5	06·02		5	,,	,,	75·9
	04·660	04·65	4r				,,	,,	85·5
	01·945		1	01·9		2n r	,,	,,	27005·2
				01·47		1	,,	,,	08·7
	3699·684		1				,,	,,	21·7
				3694·25		1n r	1·02	,,	61·5
3680·048							,,	7·7	27165·8
72·147	72·164 K	3672·13	2	65·5		1b	,,	,,	27224·3
	62·220 K	62·24	2	62·24		3	,,	,,	98·0
				58·7		1n	,,	,,	27324·4
50·313	50·328 K	50·38	4	50·31		4	1·01	,,	87·1
49·661	49·663	49·69	4	49·66		1	,,	,,	92·0
45·547	45·561 K	45·58	5	45·57		8	,,	,,	27422·9

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
3641·675	3641·677 K	3641·69	4	3641·8		2b	1·01	7·7	27452·1
	37·303 K	37·30	3	37·45		3	,,	7·8	84·7
	36·819 K	36·80	2				,,	,,	88·8
	28·980 K	28·97	3	29·00		1	,,	,,	27548·1
	21·893		1n	21·96		1	,,	,,	27601·8
	13·249 K	13·24	2				,,	,,	68·1
	12·496 K	12·50	1	12·53		2n r	1·00	,,	73·6
				10·5		2n	,,	,,	89·2
				09·4		1n	,,	,,	97·6
	01·201 K	01·19	1	01·20		1	,,	,,	27760·7
	3593·443		2				,,	7·9	27820·7
	81·994 K		2	3582·0		1b	,,	,,	27909·6
				80·3		1b	,,	,,	22·8
				79·1		1b	,,	,,	32·2
3574·565	74·561 K	3574·57	4	74·60		1	0·99	,,	67·5
	66·254						,,	,,	28032·7
	63·943						,,	,,	50·9
	60·726						,,	,,	76·3
				57·88		1	,,	,,	98·7
	57·396	57·40	2				,,	,,	28102·5
	53·732						,,	,,	31·5
	50·962 K	50·98	1	50·98		1	,,	8·0	53·3
	45·095		3	45·0		1n	,,	,,	28200·0
	37·626						0·98	,,	59·5
	34·713						,,	,,	82·8
	30·805	30·79	1	30·80		1	,,	,,	28314·2
	28·726						,,	,,	30·8
				17·26		50r	,,	,,	28423·2
14·191	14·209 K	14·20	3				,,	,,	47·2
13·050	13·064	13·07	3	13·06		1	,,	,,	57·1
10·121	10·133 K	10·14	3	10·13		1	,,	8·1	80·8
	3480·750	3480·77	1				0·97	,,	28721·3
3461·327	61·331 K	61·30	2				,,	8·2	28882·5
53·312	53·311 K	53·30	3	3453·32		2	0·96	,,	28949·5
52·330	52·354 K	52·33	3	52·35		2	,,	,,	57·7
	50·785	50·79	1				,,	,,	70·7
				11·95		1n	0·95	8·3	29300·4
	04·653	04·61	1				,,	,,	63·4
	3397·882		1				,,	,,	29421·8
	88·735	3388·70	3				,,	8·4	29501·3
	81·556	81·55	1				,,	,,	63·8
3381·046	81·024 K	81·10	8	3381·10		10	,,	,,	65·1
76·472	76·451 K	76·48	3	76·45		3	0·94	,,	29608·4
	62·167 K	62·17	1				,,	,,	29734·3
	57·603	57·62	1				,,	8·5	75·6
	49·945						,,	,,	29842·7
44·05	44·682 K	44·74	7	44·71		7	,,	,,	89·5
	42·356 K	42·38	3				,,	,,	29910·4
37·630	37·611 K	37·66	7	37·67		15	0·93	,,	52·8
	07·115 K	07·15	1	07·05		1	,,	8·6	30228·9
03·241	03·239 K	03·29	5				,,	,,	64·5
				02·26		5	,,	,,	73·7

LANTHANUM—*continued.*

Arc Spectrum. Wave-length: Rowland and Harrison	Arc Spectrum. Wave-length: Wolff	Arc Spectrum. Wave-length: Exner and Haschek	Arc Spectrum. Intensity and Character	Spark Spectrum. Wave-length: Exner and Haschek	Spark Spectrum. Wave-length: Lohse	Spark Spectrum. Intensity and Character	Reduction to Vacuum: λ +	Reduction to Vacuum: $\frac{1}{\lambda}$ −	Oscillation Frequency in Vacuo
3265·795	3265·792 K	3265·81	5	3265·79		4	0·92	8·7	30611·7
49·481	49·483 K	49·50	4	49·49		3	0·91	8·8	30765·3
	47·159	47·15	1				,,	,,	87·4
45·250	45·248 K	45·26	5	45·24		4	,,	,,	30805·5
36·671							,,	,,	87·1
	35·763	35·76	1				,,	,,	95·8
15·935	15·929 K	15·94	2				0·90	8·9	31086·2
	3193·130 K	3193·15	2	3193·09		1	,,	,,	31308·4
	85·505		1n				,,	,,	83·3
	84·087		1n				0·89	,,	97·3
	79·888	79·91	1n				,,	9·0	31438·5
		79·46	1n				,,	,,	42·9
76·103	76·088	76·11	1				,,	,,	76·1
				71·79		20	,,	,,	31518·9
	48·648						,,	,,	31750·7
42·881	42·880 K	42·91	2	42·90		1	0·88	9·1	31808·5
	09·544 K	09·55	3				,,	9·2	32149·8
	08·568	08·57	2				,,	,,	60·0
04·702	04·702 K	04·70	3	04·76		1	,,	,,	99·9
	3096·124	3096·15	1				0·87	,,	32289·1
	10·924 K		2				0·85	9·5	33202·9
	2963·036 Ky		1				0·84	9·7	33739·5
	50·615 K Ky		3	2950·70		1n	,,	,,	33881·0
	2899·861		1n				0·82	9·9	34474·5
	93·185 K		4	2893·20		2	,,	10·0	34553·9
	85·249 K		4	85·25		2	,,	,,	34649·0
	80·743 K		2	80·85		1	,,	,,	34702·6
	63·056		2				0·81	10·1	34917·6
	59·842		2				,,	,,	56·9
	56·001 K		3	56·0		1n	,,	,,	35003·9
	48·445		1				,,	,,	96·8
	15·450 Ky		1n				0·80	10·2	35108·1
	08·468 K Ky	2808·48	6	08·46		3	,,	10·3	35596·3
	2798·645 K		2	2798·65		1n	,,	10·4	35721·2
	96·468 Ky		1				,,	,,	49·0
				91·60		1	,,	,,	35811·3
	80·336 Ky		2	80·3		1n	0·79	,,	56·5
	29·987 Ky		2				0·78	10·6	36619·6
				2695·59		1	0·77	10·8	37086·8
				85·1		1b	,,	,,	37231·8
			2 Cr ?	82·5		1b	,,	,,	67·9
	2677·988						,,	10·9	37330·6
				73·03		1	,,	,,	99·8
		2660·51	1				,,	,,	37575·9
				51·78		8	0·76	11·0	37699·5
	10·128 K	10·43	2b	10·46		5	,,	11·1	38296·7
				2596·20		1n	0·75	11·2	38506·6
				60·50		1n	0·74	11·4	39043·5
				19·31		2	,,	11·6	39681·8
				2487·65		1	0·73	11·8	40186·8
				76·80		7n	,,	,,	40362·9
	2471·990		1	72·0		1n	,,	,,	40441·2

LANTHANUM—*continued.*

Arc Spectrum				Spark Spectrum			Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length		Intensity and Character			
Rowland and Harrison	Wolff	Exner and Haschek		Exner and Haschek	Lohse		$\lambda+$	$\frac{1}{\lambda}-$	
				2399·73		1n	0·71	12·3	41659·0
				79·49		10	,,	12·5	42013·3
				28·87		1	0·70	12·8	42926·5
				19·55		1	0·69	12·9	43098·9
				17·90		1	,,	,,	43129·6
				2297·85		7	,,	13·1	43505·8
				56·80		1	0·68	13·4	44297·1
				16·12		2	0·67	13·8	45110·1

Colloid Chemistry. *By* H. R. PROCTER, *M.Sc.*

[Ordered by the General Committee to be printed *in extenso.*]

MODERN colloidal chemistry may be said to begin with the work of Graham about 1861, though the colloids had long been known to chemists, and Faraday [1] had prepared and described colloidal gold solutions. Graham first pointed out the radical differences between the colloid and crystalloid state, and introduced most of the nomenclature now in use, such as 'sol' and 'gel' for the apparent solution and the precipitate or jelly, and distinguished their various liquid media by the prefixes 'hydro-,' 'alco-,' &c. It would be impossible to refer in detail to the various workers who have since contributed to its advance, but the following may be mentioned as marking distinct steps in its progress. Wiedemann [2] showed that the absorption of water by solid colloids is in its earlier stages accompanied by considerable evolution of heat, actual solution and the fusion of jellies by absorption, while in gelatinisation heat is evolved. He later published researches on electrical osmose and cataphoresis which have important bearings on colloidal theory. The work of Van Bemmelen, 1888 *et seq.*, on colloidal jellies and precipitates is of permanent value, and his theory of the network or cellular structure of jellies has been very generally accepted by later workers, though, in your reporter's opinion, on insufficient evidence. In 1889 M. Carey Lea published extensive researches on 'allotropic' (colloidal) silver,[3] and in 1892 Picton and Linder's work on 'Solution and Pseudo-solution' [4] opened new ideas on the nature of colloidal solution, and perhaps of solution in general. In 1893 Siedentopf and Zsigmondy, building on the earlier work of Tyndall on the scattering and polarisation of light by non-homogeneous media, invented the ultra-microscope, in which, by a special form of dark-ground illumination, particles which were much too small to give an actual microscopic image were rendered visible as points of

[1] *Phil. Trans.*, i. 1857, pp. 145–152; *Phil. Mag.* (4), **14**, 401–417, 512–539.
[2] *Verh. d. physik. Ges. zu Berlin*, 1884, p. 44.
[3] *Silliman's Jour.* (3), **37**, 476–491, **38**, 47–50, 1889.
[4] *Chem. News* and *Jour. Ch. Soc.*, 1892.

light. By this means the suspended matter in many colloid solutions has been rendered visible and the number and size of the colloid particles estimated.

Since sodium and potassium chlorides have been obtained in colloidal form in organic solvents, it is no longer possible to distinguish between colloid and crystalloid *substances*, but only between the colloid and crystalloid *state*. In the typical crystalloid solution of an electrolyte the dissolved body is separated into its molecules, and to a large extent into individual ions, while in the colloid sol the units of distribution are either large and often conjugated molecules or more frequently minute particles composed of many molecules united by cohesive attraction. Whether there is in principle any clear line dividing these conditions, or whether they do not rather shade off into each other by insensible gradations is very doubtful, but in typical cases the distinction is sufficiently marked. As osmotic pressure, and all its attendant effects are proportional to the *number* of the dissolved molecules, and therefore, for a given quantity of substance inversely to the mass of the molecules or particles, these physical effects are almost absent in the colloid sol, and in most cases diffusion, lowering of freezing point, raising of boiling-point, and *a fortiori* electric conductivity which demands ionic dissociation are barely, if at all, perceptible, and may perhaps be attributable to the traces of electrolyte which appear essential at least to inorganic colloid solution. In the cases of many organic colloids of known high molecular weight, boiling- and freezing-point determinations have yielded numbers not inconsistent with the view that the particles are actual single molecules. While crystalloid bodies can usually only be separated from solution by evaporation or freezing of the solvent, or by chemical changes, colloid sols are unstable, and liable, either spontaneously or through very slight disturbing causes—such as the addition of an electrolyte, change of temperature, or concentration—to separate into an amorphous precipitate, or 'gel,' and the practically pure solvent. While crystalloid solutions are optically homogeneous, all colloid sols exhibit, in a greater or less degree, the 'Tyndall effect' of scattering and polarising light, and, in most, minute suspended particles may be detected by the ultra-microscope. The relation of colloid sols to mechanical suspensions of very finely divided solids and to emulsions of immiscible liquids is a very close one, and may depend merely on the size of the particles. Many sols are visibly opalescent, but those with very small particles may be perfectly transparent, and metallic sols are often deeply coloured; gold sols vary from deep red to bluish violet.

The organic colloid sols differ in many respects from the inorganic, often approaching very closely to true solutions; and being usually bodies of high molecular weight, and little subject to electrolytic dissociation, their true solutions would necessarily possess many of the properties associated with colloids. It is in fact by no means impossible that very large molecules or molecular aggregates may disperse and polarise light, and may even be made visible by the ultra-microscope. Organic sols are usually more stable than inorganic, and are flocculated or precipitated by different causes, so that it will be appropriate to defer their consideration till after that of the simpler and better investigated inorganic, or, as they are sometimes called, 'suspension' colloids.

Inorganic colloid sols are invariably suspensions of very finely divided substances in media in which they are extremely insoluble, Von Weimarn[1] has shown that even the most definitely crystalloid bodies may be obtained in colloidal or gelatinised solution if produced in solutions in which they are very insoluble. An ordinary precipitate, such as barium sulphate, is at first formed by the combination of the ions in very minute crystal elements which are sufficiently soluble in water rapidly to unite to form crystals, which gradually increase in size by absorbing the smaller crystal elements. It is well known in ordinary analytical work that such precipitates will pass at first through any filter, but gradually become filterable by the effect of time and warmth. If, however, their insolubility is sufficiently increased by large excess of a common ion, or by effecting the combination in a medium, such as methyl alcohol, in which sulphates are extremely insoluble, the molecules cannot coalesce in the crystalline form, and a colloidal sol results. Even sodium and potassium chlorides have been obtained in colloidal form by the double decomposition of their organic compounds in organic media in which the salts were sufficiently insoluble.

Though inorganic sols are precipitated by the addition of an electrolyte, the presence of free dissociated ions in small quantity seems essential to their formation and existence. If a solution of ferric chloride be dialysed through a colloid membrane into water, the hydrochloric acid formed by hydrolysis passes out into the water, leaving the ferric oxide in the dialyser as a colloid sol, and this goes on till the sol is practically free from chlorine, but if absolutely the last traces are removed, the ferric oxide flocculates and precipitates. Conversely, many oxide or hydroxide sols may be obtained by washing the precipitated hydroxide sufficiently free from electrolytes, or the precipitated and washed hydroxide may be redissolved by boiling with a very small quantity of neutral salt or free acid, when the precipitate will gradually pass into colloidal solution. This process (peptisation, Anätzung) has been extended to the colloidal solution of mechanically finely powdered oxides by the agency of small quantities of acids or salts, and has been employed by Kužel[2] to bring many metallic oxides into the plastic condition requisite for the formation of the so-called 'colloid' electric-lamp filaments, now rapidly superseding the carbon fibre. Colloid sols are frequently formed by the free dilution of salts liable to hydrolytic dissociation, and especially salts of weak organic acids which from their low electrolytic dissociation do not readily cause precipitation. Even ferric chloride at a dilution of 1 : 125000 is completely dissociated in the cold in twenty-four hours, and much stronger solutions suffer partial dissociation, especially on heating. This is the cause of the darkened colour of hot ferric solutions. Acetates are still more readily hydrolysed, and especially by boiling, by which the free acetic acid is volatilised. Many solutions of hydroxides in alkalies are colloidal, but those in ammonia are usually true complex salts. Colloidal solutions are obtained of sulphides of metals of which the oxides, like those of arsenic and antimony, are soluble in water, by precipitation with H_2S, only water and the sulphide being formed in the reaction; and metallic sols of gold, silver, platinum, and other noble metals are formed by reduction of their dilute solutions, particularly with organic reducing agents. Many sols may also be made by precipitation in presence of organic

[1] *Z. Ch. u. Ind. d. Kolloide*, ii. 1907, p. 76.
[2] *D. R. P. Anmeld*, 12*g*. *K*. 30900 of Dec. 12, 1905.

'protective colloids' which prevent precipitation by electrolytes. Thus silver halides may be obtained in colloidal solution in presence of gelatine, a fact of great importance in photographic-plate making. An interesting point is that in many cases the nature of a sol may be changed by oxidation, reduction, or chemical substitution without destroying its colloidal character.

An important method of producing metallic sols is that of Bredig,[1] which differs in many respects from those just described. He employs the metal as cathode of an electric arc formed under water, which forms a sol with the particles projected from the cathode. Svedberg[2] has applied the same method to the production of sols in ether, isobutyl alcohol, and other organic liquids, and of carbon, silicon, sulphur, and phosphorus in water.[3] Bredig and Haber[4] have also shown that under certain conditions sols can be produced by electrolysis, especially in alkaline solution.

The ultra-microscope of Siedentopf and Zsigmondy[5] has rendered many details of colloid sols accessible to direct observation. In its original and most complete form it consists of a rectangular cell on the stage of the microscope, through the side of which a powerful horizontal beam of light is concentrated by appropriate lenses and adjustable slits; but several other types have been constructed for special purposes. No light can reach the observer but that from the brilliantly illuminated particles, which are thus rendered visible irrespective of size, as stars are visible to the naked eye on which the most powerful telescope can raise no measurable disc. As the field of view, and the vertical thickness of the beam can be accurately measured, it is possible to count the visible particles in a given volume of liquid, and as the total concentration is known, their weight (and on certain assumptions as to form, their size), can be calculated. While the diameter of the smallest particles which could be seen by ordinary illumination, even with a magnifying power of 2250 diameters, is about 140 $\mu\mu$ (mm. $\times 10^{-6}$) Zsigmondy has observed particles in gold sols of from 20 to 80 $\mu\mu$ (submicrons) while still smaller particles (amicrons) exist, which scatter and polarise light, but cannot be separately distinguished. Zsigmondy estimates the size of the smaller of these amicrons as from 1·7 to 3 $\mu\mu$ (0·0000017 to 0·000003 mm.). Ostwald[6] gives the probable size of a hydrogen molecule of molecular weight 2 as about 0·16 $\mu\mu$. As organic substances certainly exist having a molecular weight of several thousand, it seems quite probable that some of them may be visible to the ultra-microscope. Vanino and Hartl[7] have shown that if a small quantity of a ready-formed gold sol be added to a solution of a gold salt and a reducing agent, the colloid particles act as nuclei for the reducing gold. It is thus possible to build up amicrons to sub-microns which can be seen and counted. Some similar action takes place in gold ruby glass, which has been shown by Zsigmondy to owe its colour to colloid gold particles, but which is sometimes colourless until, by reheating, the gold germs have been allowed to grow by absorbing amicrons or reducing gold salts.

[1] *Z. f. Angew. Ch.*, 1898, 951–954; *Z. f. Elektr.*, 1898, **4**, 514–515.
[2] *Ber.*, 1905, **38**, 3616–3620.
[3] *Ibid.*, 1906, **39**, 1713. [4] *Ibid.*, 1898, **31**, 1741.
[5] *Zur Erkenntniss der Kolloide*, Jena, 1905.
[6] *Grundriss*, p. 82.
[7] *Ber.*, 1906, **39**, 1696–1700.

Other metallic and inorganic sols appear to contain particles of the same order of magnitude as the gold sols, but different sols vary considerably, and any sol contains a mixture of particles of various sizes.

As seen by the ultra-microscope, the particles are not at rest, but in constant rapid vibrating movement, and, according to Zsigmondy, gold particles have also a translatory motion. This vibration, which certainly plays its part in the physics of colloid sols, is identical with the Brownian or pedetic motion common to all minute particles suspended in liquid, but more marked in the ultra-microscopic, since it increases inversely with the size of the particles. This motion increases with temperature and diminishes with increased viscosity of the liquid, but is permanent and unaffected by time, or apparently by the exclusion of radiant heat and light. All theories therefore which ascribe the energy involved to outside influences would seem to be excluded, but it must be remarked that it is impossible to *observe* the phenomenon without light, and, ultra-microscopically, without light of a very intense character, so that the view suggested by Regnauld [1] that it was due to the warming of the particles by radiant heat cannot perhaps even yet be entirely ignored. Sir W. Ramsay [2] suggested that the motion was directly due to the heat-vibration of the water-molecules, though he thought it necessary to assume highly complex water-molecules to account for the disturbance of the much heavier solid particles. Einstein [3] and Smoluchowski [4] have discussed the phenomenon mathematically from two entirely different physical standpoints, and have reached results which not only show a scarcely expected concordance with each other, but a close relation to observed facts. The experimental work of Svedberg [5] also strongly supports this view, so that, without presuming to discuss the mathematical evidence, it appears that a strong case is made out for regarding the motion as a direct consequence and evidence of the kinetic theory of heat. It may be remarked that if external sources of energy can be excluded, heat-motion seems the only available cause, since all the energy involved in overcoming internal friction of the liquid is converted into diffused heat, which in a space of uniform temperoture cannot be retransformed into any other form of energy.

If an electric current of sufficient strength be passed through an aqueous electrolysable solution in which the anode and cathode are separated by a diaphragm of porous earthenware, the liquid will pass through the latter towards the cathode till a certain equilibrium pressure is established. The phenomenon is known as 'electrical osmose' or 'cataphoresis.' Although observed by Reuss in 1809, the subject was first systematically investigated by Wiedemann.[6] He showed that, with uniform difference of pressure, the quantity of liquid which passed through the diaphragm was proportional to the current-strength and independent of the area or thickness of the porous plate; and the pressure attained, when equilibrium was reached, to the potential difference between the two sides of the diaphragm. Quincke,[7] substituting a

[1] *J. d. Pharm.* (3), 1857, **34**, 141. [2] *Chem. News*, 1892, **65**, 90.
[3] *Ann. Phys.* (4), 1905, **17**, 549–560; and 1906, **19**, 2.
[4] *Ibid.* (4), 1906, **17**, 756–780.
[5] *Ark. för Kemi, Min. och Geol.*, 1907, **2**, *Nr* 29 and 34.
[6] *Ann. Phys.* (2), 1852, **87**, 321; and *Die Lehre der Elektrizität*, 1893, Bd. I., 993–1019.
[7] *Ann. Phys.* (2), 1861, **113**, 513–598.

capillary tube for the diaphragm, confirmed these laws, and showed further that the equilibrium-pressure increased with diminished bore and relatively increased surface of the capillary; and that not only the pressure, but the direction of the flow were dependent on the nature of the material of the capillary and the liquid employed; oil of turpentine flowing to the anode in a glass capillary, and in the reverse direction in one lined with sulphur. It is obvious, therefore, that the action is between the surface of the liquid carrying the electric current and that of the capillary, and that if the liquid were fixed and the capillary surface free to move, it would be carried in the opposite direction to the flow of the liquid. This will be the case with suspended particles; and it has long been observed that these are carried in one or other direction according to their material and that of the liquid, most substances moving toward the anode in water and the cathode in turpentine, with a velocity proportional to the current-strength, but independent of their distance from each other, and of the electromotive force. Quincke assumed that the particles possessed electrical charges different from the liquid, and usually negative as compared with aqueous solutions; so that in a current the — particles would tend to move to a region of higher + potential, that is, towards the anode. The relation of these facts to the contact-theory and to the phenomena of frictional electricity is obvious; a stream of liquid forced through a capillary of different potential would necessarily give rise to an electric current if furnished with appropriate conductors.

Helmholtz supported and somewhat amplified the hypothesis of Quincke.[1] According to him, the limiting surfaces of two bodies of opposite electric character form a 'double layer' (Doppelschicht); the + charge of the one layer exactly equalling the — charge of the other, and thus exerting no outside effect. Under the influence of a fall of potential the liquid layer tends to move over the other, and by friction communicates its motion to the adjacent liquid. Billitzer[2] supposes that the liquid coating of the double layer communicates its charge by diffusion to the remainder of the liquid, and, as this charge is constantly renewed by contact-action, both liquid and particles assume permanent charges, so that the latter behave, in a certain sense, like free ions. It is possible, or indeed likely, that the particles owe their original charges to the actual attachment of free ions by their residual affinities. It is not necessary to suppose, or even probable, that when two or more atoms unite to form a molecule their affinities are quantitatively saturated, but merely that, under the conditions, the residual affinity is insufficient to attach another atom. Under these circumstances it is likely that a mass of molecules may be able to hold additional ions in a way probably identical with what is known as 'adsorption'; and these ions will affect the charge of the mass. The bearing of this on the phenomena of flocculation will be referred to later.

The phenomenon of electric cataphoresis was first studied with fine mechanical suspensions, and has been employed technically for clearing turbid liquids, and more recently for drying pasty mixtures, such as alizarine paste or ground peat; currents of high potential being used. It is, however, very marked in colloid sols, and closely simulates actual

[1] *Ann. Phys.* (3), 1879, **7**, 337.
[2] *Wien. Ber.*, 1903, **112**, 95–139.

electrolysis. Spring,[1] Lottermoser,[2] and others give the following lists as to the behaviour of particles in aqueous sols :—

Wander to Kathode. +	*Wander to Anode.* −
Metallic hydro-oxides generally.	Colloidal metals.
Methyl violet.	Metallic sulphides.
Methylene blue.	Silver halides.
Magdala red.	Sulphur.
Titanic acid.	Selenium.
	Aniline blue.
	Indigo.
	Eosin.
	Fuchsin.
	Mastic.

Many organic colloids, and some mineral ones (*e.g.*, silicic acid), wander to the anode in alkaline and the cathode in acid solution, while certain neutral substances in water, and many others in suitable mixtures of water and alcohol, are electrically indifferent. Definite charge in relation to the medium is not therefore essential to the colloid state, though it appears to be so to electrolytic flocculation.

From what has just been said, it may be concluded that colloidal solutions must possess a sort of pseudo-electrolytic conductivity ; but if this is the case, the amount is so slight that it is difficult to decide whether it depends on the colloid particles or on the residual traces of electrolyte, from which it is impossible to free the sols, as it but slightly exceeds that of the purest attainable water. Undoubtedly the particles do carry charges ; but the charges are small, and the motion slow, and the number of moving particles very small compared with the ions in an ordinary electrolyte. It is also uncertain whether the particles are actually discharged at the electrodes, though occasionally particles appear to be repelled from both poles, and to collect in the middle of the liquid, which may be due to those which have reached the electrode and received a contrary charge wandering backwards, and encountering and attracting originally charged particles proceeding in the opposite direction.

All inorganic sols are flocculated and precipitated by the addition of electrolytes, though they vary in sensitiveness. Organic sols are much less sensitive in this respect, but are frequently flocculated by the addition of organic solvents such as ether or alcohol, to which inorganic sols are usually indifferent. The precipitate is usually termed the 'gel,' but the term must not be confounded with 'jelly' to which many of the gels are but distantly related. Gels may be 'reversible,' and may readily return to the sol state on restoring the original conditions, such as removing the added electrolytes ; but frequently they are 'irreversible,' that is, the sols cannot be restored without going through the often complicated operations by which they were originally produced.

While the phenomenon of flocculation is apparently similar in inorganic and organic sols, it probably often differs rather widely in its causes, that of inorganic sols being closely connected with the electric charges of the particles ; while in organic sols, osmotic effects which will be best discussed in connection with the properties of jellies, have

[1] *Bull. Acad. Roy. Belg.* (3), 1898, 35, 780.
[2] *Anorganische Kolloide*, p. 76.

probably a preponderating influence. Organic sols which have received definite charges usually behave with electrolytes like the inorganic.

Spring has pointed out that 'coagulation' (flocculation and precipitation) takes place in two stages, though both may proceed simultaneously. In the first, the particles flocculate or adhere in larger aggregates; and in the second, these precipitate or settle under the influence of gravity. The rapidity of this second stage is much influenced by the size and density of the aggregates and the viscosity of the liquid, while the first stage is more clearly marked by the beginning of turbidity or opalescence, and, though not usually instantaneous, is better suited to observation.

Numerous experiments have shown that in order to produce flocculation, the concentration of the electrolyte must reach a certain minimum value ('Schwellenwert'), which varies with the electrolyte and the sol from a mere trace to a considerable amount.

Below this value, lapse of time produces no change, but, once it is passed, the sol is rapidly or slowly precipitated. In each case that ion of the electrolyte which has the opposite charge to the particles of the sol, has the determining effect, which increases rapidly with its valency. It has been stated that with divalent and trivalent ions it is proportional to the square and cube of that of monovalent, and Wetham[1] has shown that such a relation can be accounted for on the theory of probabilities with certain assumptions as to the electric charge required for coagulation; but the agreement of the observed numbers with each other and with those required by theory is not sufficiently close to make such speculation of much importance. It is also evident that the proportion will vary with the numerical value assumed for the monovalent ion. Perhaps more important is the observation of Hardy[2] that the specific conductivities (ionic dissociation) of acid solutions exerting equivalent coagulating powers on negative and of alkaline on positive colloids are approximate constants; while acid solutions on positive and alkaline solutions on negative colloids have very varied values. This probably simply means that free H and free OH ions each have constant precipitating values for the colloids of opposite sign, while the acid and basic ions act according to their nature and valency.

It has been stated by Spring[3] and others that the superior influence of polyvalent ions was not due directly to their valency, but to the usually greater hydrolytic dissociation of their salts, and, though this has been contradicted, it is not probable that the different ionic concentration produced by hydrolysis is without influence. Jordis[4] considers that the colloid state and its phenomena are due to complex chemical compounds.

When a colloid sol is precipitated by an electrolyte the resultant gel always contains a small and apparently definite quantity of the precipitating ion of opposite sign to the particles, which cannot be removed by washing without restoring the gel to the sol condition, or destroying its colloidal character. This quantity is proportional to the equivalent weight of the precipitating ion, and may, in many cases, be substituted

[1] *Phil. Mag.*, 1899 (5), **48**, 474–77.
[2] *Proc. Roy. Soc.*, 1899, **66**, 110–125.
[3] *Rec. Trav. chim. Pays-Bas*, 1900, **19**, 204–236.
[4] *Z. f. Elektr.*, 1904, **10**, 509–518; *Sitzungsber. d. phys.-med. Soc. Erlangen*, 1904, 36, 47–107; *Z. f. Elektrotech.*, 1904, **10**, 509–518; and Kanter, *Z. anorg. Ch.*, 1903, **35**, 16–22.

by another ion of the same sign by washing with the appropriate salt.[1] In each case an equivalent quantity of the non-precipitating ion is set free, and in the case of the stronger acids and bases may be estimated in the residual liquid by titration. These phenomena are not confined to inorganic colloids, but are very marked in many organic colloid precipitations, and apparently the same laws hold good in many pseudo-solutions, such as that of clay or of gum mastic in water, which are generally distinguished as mere mechanical suspensions. The phenomenon of the retention of a portion of the precipitating ion with the precipitate is well known in many ionic reactions, and is usually termed 'co-precipitation' or 'adsorption.' It is in fact common to all bodies of largely extended surfaces and to jellies, though the question whether in the last case the action is surface, or extends throughout the substance, must be discussed later. Even with solids, this is still, to a certain extent, an open question. Davis[2] has shown that in the absorption of iodine by carbon, an equilibrium is established with the surface action in a few hours, but that a further absorption goes on for weeks or months, which he considers due to solid solution. The quantity of absorbed or adsorbed substance varies with the concentration of the solution with which it is in equilibrium, relatively more being taken from weak than from stronger solutions. The laws by which it is governed show close relations to those of solution-equilibria, and the phenomenon might perhaps be not improperly described as surface-solution. If a body be brought in contact with two immiscible solvents, it distributes itself between them in a ratio which, so long as its molecular condition is the same in both solvents, is, in accordance with Henry's law, a constant fraction dependent on its relative solution-pressure in the two solvents; or if C_a and C_b be its concentration in the solvents a and b and β a constant, $C_a=\beta C_b$. If, however, its molecular weight in the solvent b is n times as great as in a, the equation takes the form $C_a=\beta C_b^{\frac{1}{n}}$. Written in a general form, where x is the weight of the absorbed substance and m that of the absorbent, while C_b is the concentration of the solution, the equation becomes $\frac{x}{m}=C_a=\beta C_b^{\frac{1}{p}}$,[3] where β and p are constants to be determined experimentally, and represents very approximately most adsorption-equilibria; but it is evident that p cannot represent the molecular weight in the ordinary sense, since it is seldom a whole number, and usually indicates greater complexity in the solvent than in the adsorbent, which is impossible, when, as in the case of most electrolytes in very dilute solutions, the dissolved body is

[1] Linder and Picton, *Jour. Chem. Soc.*, 1895, **67**, 63.

[2] *Trans. Ch. Soc.*, 1907, **91**, 1666–1683.

[3] The exponential character of a curve of experimental results is easily tested by plotting the logs, either natural or common. If the logs of the equation $C_a = \beta C_b^{\frac{1}{p}}$ be taken, we obtain $\log C_a = \log \beta + \left(\log C_b \times \frac{1}{p}\right)$. Hence, if we plot the experimental logarithmic concentrations of the solution as abscissæ and those of absorbed substance as ordinates, we shall, if the reaction is rigidly exponential, obtain a straight line, of which the slope (tangent) is $\frac{1}{p}$, and which cuts the vertical line, passing through the origin $\log C_b = 0$ (or $C_b = 1$) at $\log \beta$. It must not be forgotten in plotting logarithms that in fractional numbers the indices are $-$, while the mantissæ are always $+$. Exponential curves rise rapidly at first, but afterwards much more slowly and approximate to a straight line.

not merely monomolecular, but almost wholly ionised.[1] The exact physical significance of p therefore remains to be determined, but where the case is one of surface-action $\frac{x}{m}$ is obviously an arbitrary expression, which is proportional for any one adsorbent in a uniform state of division, but gives no indication of the absolute surface involved. Even if the surface is molecular, as it probably is in jellies, we have little knowledge of the complexity of the molecules. It can hardly be doubted that adsorption is dependent on the same forces as solution, as it is obviously selective and influenced by the chemical relations of the adsorbed and adsorbing substances, and in some cases is a preliminary to actual chemical combination.

Freundlich[2] has suggested a somewhat different empirical formula from that given above for expressing adsorption, the so-called λ formula, in which λ for a given original concentration of the adsorbed solution is constant and independent of the quantity of adsorbent, and takes the place of β in the simple equation expressing Henry's law. If, however, the concentration of the solution (*i.e.*, the relation of the dissolved substance a to the volume of the solution v) is varied, $\lambda = \alpha \left(\frac{a}{v}\right)^{-\frac{1}{n}}$, where α and n are constants dependent only on temperature and the nature of the dissolved substance. This formula has been severely criticised by Bain,[3] who shows that in some cases it leads to quite anomalous results. Freundlich adopts the view of Lagergreen,[4] that adsorption is due to surface-tension, and points out that a dissolved body which lowers the surface-tension between solution and solid must become concentrated on that surface. That this is an actual factor in adsorption admits of no doubt; but our knowledge is not yet sufficient to enable us to calculate its magnitude; and it would seem to imply that adsorption was independent of any direct relation between the adsorbed and adsorbing body, which does not appear to be the case. It may be, however, that chemical relations between the solid and the dissolved substance influence the tensions of the solid-liquid surface, and so affect the results.

Inorganic sols are frequently coagulated by freezing or evaporation, and this is often really due to the traces of electrolytes always present in the sols, which become concentrated in the remaining liquid till they reach the minimum necessary for flocculation.

Colloid sols are not only flocculated by ions but by other sols of opposite charge, the two colloids precipitating together in a way which closely simulates an ionic reaction; and many precipitations usually considered chemical, such as those of tannin and gelatine, tannin and basic colours, and basic with acid colours are of this character. If the two sols are present in exactly the right proportions the precipitation is complete, and the precipitate of almost constant composition; but if one be in excess neither is completely precipitated. Probably in this case, as in flocculation by electrolytes, there is a minimum concentration below which precipitation does not take place.

The cause of this minimum concentration being needed is not clear,

[1] Cp. Walker and Appleyard, *Trans. Ch. Soc.*, 1896, **69**, 1334.

[2] 'Ueber die Absorption in Lösungen,' *Habilitationsschrift*, Leipzig, 1906.

[3] *Trans. Ch. Soc.*, 1907, **91**, 1683.

[4] *Bihang t. Svenska Vet. Ak. Handl.*, 1899, **24**, II., Nr. 4, 49; *Z. phys. Ch.*, 1900 **32**, 174, 175.

but it seems to indicate a certain initial resistance which must be broken down, and which is probably connected with the surface-tension between the particles and the liquid, or possibly with the stability of the electrical double layer, with which the surface tension is closely connected, as shown by the work of Quincke and Lippmann. The resistance to electrolytes is somewhat affected by the rate at which they are added, being greater when the addition is slow or in small quantities than when the necessary amount is added at once.

It can hardly be doubted that flocculation, whether by added electrolytes or by other colloids, is dependent on the neutralisation of the charges of the particles. In the case of electrolytes, the ions of which the charges are much greater than those of the particles, probably act as nuclei round which a number of particles are aggregated. The greater efficiency of polyvalent ions may thus depend on the larger aggregates which their larger charges are able to neutralise, and which naturally fall sooner under the influence of gravity and of cohesive attraction. As the particles probably owe their charges to attached ions, both flocculation and adsorption are in a sense chemical reactions. As one ion probably neutralises many particles, the quantity carried down with the gel is relatively very small.

The action of 'protective' colloids has been already mentioned, and is usually most marked in the effect of organic colloids on inorganic sols, but certain inorganic sols have also protective effect. Biltz[1] found that zirconium hydroxide exerted a protective action on gold sols even stronger than that of gelatine; and Ruer,[2] that zirconium and ferric sols containing traces of chlorine gave no precipitate with silver nitrate, the silver chloride remaining in colloidal solution. Kuspert has also produced gold and silver sols by reduction in presence of silica jelly. The efficiency of protective colloids extends to both positive and negative sols, though usually in different degrees, and is marked in a large number of organic colloids, many of which, it may be remarked, are amphoteric, and take different charges according to the acidity or alkalinity of the medium. Thus gelatine and its peptones are among the most powerful with regard to gold sols, less than 1 mgr. being sufficient to protect a litre of gold sol from precipitation by salt, while 80 mgr. were required to exert an equal protective effect on a (much more concentrated) As_2S_3 sol. Most other colloids are less powerful in their effects, 10–20 mgr. of egg albumen, a somewhat larger amount of gum arabic, and from 0·6 to 2 grm. of dextrine or starch being required to produce on gold sol an equal effect to 1 mgr. of gelatine. Zsigmondy[3] has taken advantage of this difference of effect for the detection and identification of colloids in mixtures. He calls the number of mgr. of a colloid required to protect 10 c.c. of a stable gold sol containing 0·0053–0·0058 per cent. of gold from the precipitating action of 1 c.c. of a 10 per cent. salt solution the 'gold-value' of the colloid.

The cause of protective action is not fully explained. It is not due to the viscosity of the colloid, since the effect is produced by quantities too small to have any appreciable influence either on the viscosity of the liquid or on the pedetic motion. Neither does it appear due to direct influence on the charges of the particles, since many colloids protect both positive and negative sols. It is more probably due to an actual coating of the particles of the sol with the protective substance. Bechhold[4]

[1] *Ber.*, 1902, **35**, 4431–8.
[2] *Z. anorg. Ch.*, 1905, **43**, 85–93.
[3] *Z. anal. Ch.*, 1902, **40**, 697–719.
[4] *Z. phys. Ch.*, 1904, **48**, 385–423.

ascribes this to surface-tension. Quincke[1] has shown that in a system of immiscible liquids A, B, and C, if the sum of the surface-tensions between A—B and B—C is less than that between A—C, B must spread between A and C, forming an intermediate layer. Bechhold shows numerically that this is the case in the system mastic-gelatine-water, and that the mastic particles must therefore become coated with gelatine, which acts as a protective colloid to a mastic suspension. It is obvious that as the gelatine-coated particles have greater attraction for water and less for each other as compared with mastic, they will have less tendency to coalesce. It may also be suggested that the gelatine may form a permanent double layer in the electric sense, which will render the neutralisation of the particles by oppositely charged ions difficult or impossible.

Platinum and gold sols exert a strong catalytic influence similar to that of platinum black and spongy platinum, decomposing hydrogen peroxide, causing combination of oxygen and hydrogen, and other similar effects. These seem merely due to the extended surface and very fine division of the metals, and belong rather to the general theory of catalysis than to that of the colloid state. Metallic sols have, however, been styled 'inorganic ferments' from the analogy of their action to that of the catalases, which are also colloidal, and which bring about similar reactions. Like them the action of the metallic sols is favoured by warmth, and in the case of hydrogen peroxide by small additions of alkali, while larger quantities slow or prevent it. In both cases certain substances, such as hydrogen sulphide and cyanide, exert a 'poisonous' or inhibitory effect on the catalyst, which if slight is slowly recovered from. It is doubtful, however, if the resemblance is more than analogy.

The colour of metallic hydrosols is often intense, and varies with their condition, and especially on approaching flocculation; that of silver from dark brown to brown-violet, changing to deep green before flocculation. Gold hydrosols vary from intense red to blue-violet, taking the latter tint before precipitation by electrolytes, though some blue-gold sols are stable. The change of colour does not depend on the average size of the particles, but apparently on their aggregation. Kirchner and Zsigmondy[2] found that a red-gold sol rendered stable by gelatine becomes blue on evaporation to dryness, and under the microscope shows intensely coloured masses of many submicrons in a colourless medium. On moistening or redissolving these become again distributed, and the red colour is restored. Planck[3] has shown that the light absorbed by small particles, which act as 'optical resonators' to the electro-magnetic light-wave, must become redder and that transmitted bluer as they approach each other. Seen in the ultra-microscope the gold particles usually reflect yellow light.

It has been noted that the precipitated gels of inorganic colloids are, in the opinion of the writer, not identical in structure with the true organic jellies, but at least in many cases they possess strong points of resemblance, and from their fine state of division retain many colloidal properties, most marked, of course, when they are reversible. They usually retain a portion of water with great obstinacy, so that it has often been mistaken for water of true chemical hydration. In some cases, however, the gels are probably true hydrates, which retain additional water by their surface-attraction. Van Bemmelen, Bütschli, and others

[1] *Ann. Phys.* (3), 1888, **35**, 580–642. [2] *Ibid.* (4), 1904, **15**, 573–595.
[3] *Ibid.* (4), 1900, **1**, 69–122.

have assumed various netted, cellular, and micellar structures in gelatinous gels, and to a certain extent these must have a real existence, though the extension of the theory to the true organic jellies is of doubtful validity. Von Weimarn[1] has shown that gelatinous precipitates are obtained when concentrated solutions of crystalloids are mixed which react with each other to produce a compound which is very insoluble in the liquid; as, for instance, when concentrated solutions of barium thiocyanate and manganese sulphate are shaken together. These 'jellies' may even be perfectly clear and transparent, and consist of drops of one or other solution, surrounded by a thin film of practically colloidal precipitate, which prevents coalescence and further reaction with the surrounding liquid. A very similar effect has been observed by the writer when a concentrated solution of calcium phosphate in hydrochloric acid is mixed with strong ammonia, when the mixture, though smelling strongly of ammonia, may yet contain acid calcium phosphate in excess, which is only slowly decomposed by the diffusion of ammonia into the isolated droplets.[2] The colloid particles are necessarily extremely insoluble in their media, and whenever precipitation occurs by the mixture of a precipitating solution the gel will be likely to take such cellular forms, the dimensions of which will depend on the conditions of precipitation. In other cases where the precipitation is more gradual the particles will still adhere to loose amorphous masses, presenting a very large surface to the liquid, and it is probable that where dilute colloid solutions coagulate in which the surface-tension between the particles and water is considerable they will cohere to a more or less molecular network, which will contract in order to lessen surface and tear into flocculent masses, entangling and carrying down with them, as albumen does, all suspended particles in the liquid. Bütschli[3] found that many gels showed network structures under the microscope with magnifications of about 2,000 diams. when suitably treated, and detected similar structure in gelatine when hardened with alcohol or chromic acid; but as the unhardened gelatine appeared quite structureless it is very probable that the cavities were produced by the hardening process, and it may be noted that gelatine rapidly hardened by dehydrating agents is always more or less opaque and non-homogeneous.

The drying of gels is a continuous process, proceeding rapidly at first with vapour pressures not materially below that of water, but gradually becoming slower, and the vapour-pressure lower as dryness is approached. Owing to the structure of the gel some time (days or weeks) is required for the mass to reach equilibrium with any definite vapour-pressure. The curve of vapour-pressures as compared with gradually diminishing percentage of water, though continuous, is not always regular, and does not appear to be exponential, and the process is usually irreversible with inorganic gels, or at least partially so, indicating a permanent change of state, though in some cases it may be connected with

[1] *Z. Ch. u. Ind. d. Kolloide*, 1907, ii. 76.

[2] Cp. p 2 of reprint. Von Weimarn holds that the sole difference between the colloid and crystalloid condition lies in the extreme insolubility of the minute crystalline elements first formed, which prevents their uniting to form larger crystals, and considers that all matter is potentially crystalline.

[3] *Untersuchungen über mikroskop'sche Schäume und das Protoplasma*, Leipzig, 1892; Verh. des naturh.-med. Vereins zu Heidelberg, *N.F.*, 1892, 5, 28–41, 42–43; 1894, 5, 89–102, 230–292; 1896, 5, 457–472.

surface-tension, as in that of swollen gelatine drying in saturated water-vapour, which will be mentioned later. Silica-jelly, which was very fully investigated by Van Bemmelen,[1] may be taken as an example. The fresh gel was dried at a temperature of 15°, at which water has a vapour-pressure of 12·7 mm., in a series of exsiccators containing sulphuric acid diluted to known vapour-pressures, until equilibrium was established. The fall of vapour-pressure was at first very gradual, but became more marked at 11 mm. when a water-content of 3·7 was reached. (It is not clear from the diagram whether this is 3·7 mols. per mol. of SiO_2 or 3·7 grm. per grm., but probably the former.) At a pressure of about 5 mm. and a water-content of about 1·5 the gel, which had previously been transparent, became opalescent, and finally porcelain-white, and the curve ran horizontally, that is, the vapour-pressure remained constant until a water-content of 1 was reached. This constant pressure indicates some change, chemical or physical, which takes place at this pressure, and if the proportions are molecular, might correspond to the decomposition of a definite hydrate $(SiO_2)_2OH_2$ with a vapour-pressure of 5 mm., or to a change of form to one with lessened attraction for water. The opacity would also correspond to some definite change, as during the horizontality of the curve the gel would be a non-homogeneous mixture of the two substances or two forms. Below 5 mm. the gel again becomes homogeneous and transparent. Van Bemmelen supposes that during the change a further coagulation takes place with contraction of the gel and the production of air-spaces. Up to this point the curve is irreversible, that is, the gel will not absorb moisture in the same way, but only a much lessened quantity in saturated water-vapour. Probably in the earlier part of the curve the surface-tension between the water and silica is different from its surface-attraction for water-vapour, and the change indicated by the opaque state is not likely to be a reversible one. Below 4 or 5 mm. pressure the drying is a reversible one, and of the character common to all porous or finely divided substances. The drying of ferric hydroxide is very similar in character, but has no marked horizontal in its curve, which is throughout irreversible. From some, perhaps rather fanciful, resemblance of the curves produced to those caused by the hysteresis or 'lag' in the magnetisation and demagnetisation of iron, the phenomenon has been described by that name. It produces some curious consequences, of which space does not permit discussion.

Most organic colloids seem to differ somewhat widely from the inorganic sols and gels which have been described, and in many cases their solutions, though possessing colloidal properties, approximate closely to what we should anticipate of true solutions of bodies of the high molecular weights which many of them are known to possess. They present more analogy to emulsions of immiscible liquids which become more miscible at higher temperatures than to suspensions of solid particles like the metallic sols, and have hence been called 'emulsion colloids.' Their sols usually show the Tyndall effect, and frequently, but not always, submicrons are visible to the ultra-microscope; but both may disappear with rise of temperature or the addition of a 'common solvent.' They are not usually sensitive to small additions of an electro-

[1] *Z. anorg. Ch.*, 1896, 13, 233–256.

lyte, and when 'salted out' by larger quantities the effect seems often more osmotic than electrical. In some cases, however, when the colloid has acquired a definite positive or negative (ionic) charge it becomes much more sensitive to electrolytes, and where organic sols mutually precipitate each other, the presence of a trace of electrolytes is probably essential to communicate the necessary charges. It is stated that gelatine free from inorganic constituents only gives a slight opalescence with tannin, and in ordinary cases the rapidity and completeness of the precipitation are much increased by the presence of salts.

Many aqueous organic colloid solutions are flocculated by additions of alcohol, ether, &c., and, conversely, alcoholic by addition of water, which have usually no action on inorganic sols. These effects are probably purely osmotic and dependent on the solubility of the substance in the different media, but such additions often change the electrical charge of the solvent.

In most cases organic sols are simply viscous liquids which on concentration become more and more viscous till they reach a practically solid form without any break of continuity; but others, usually by change of temperature, pass into the semi-solid state known as jelly. This solidification generally occurs with comparative suddenness, and is sometimes irreversible, but usually jellies have pretty definite melting-points at or slightly lower than their points of solidification, and varying only slightly with the concentration of the solution, but, like the melting-points of fats, not reaching their full value till some time after apparent solidification. Like crystallisation also, the change to the solid form is accompanied by evolution of heat, and liquefaction by its absorption.

Conversely, organic colloids in the solid form are capable of absorbing water or some other solvent, sometimes passing back without break to the viscous condition, but often reaching a maximum absorption and retaining the jelly state. Gelatine, for instance, dissolves direct to a viscous solution at temperatures above 25° or 30°, but swells to a jelly at lower ones, which melts if the temperature is raised. Cellulose and many of its derivatives and many animal and vegetable tissues swell, but do not dissolve without hydrolysis or other chemical change, and may be viewed as irreversible jellies. Thus dyeing, tanning, and many other industries may be regarded as branches of colloidal chemistry.

The absorption of the solvent is accompanied by swelling or increase of volume, but especially in the early stages by marked contraction of the sum of the volumes of solvent and colloid, and considerable evolution of heat; and, conversely, in dehydration heat is absorbed. Consequently cold promotes swelling (as distinguished from solution), and heat has the opposite effect, though in dilute jellies, which can usually only be subjected to a small range of temperature, these effects are not very marked, and are often masked by other influences such as bacterial fermentation. As an illustration, it may be mentioned that gelatine is most rapidly and satisfactorily dissolved for culinary purposes by swelling in cold water, which may be thrown away with the dissolved impurities, and then by melting the swollen jelly by setting the vessel in hot water.

The absorption of water-vapour by most solid organic colloids is a cyclical and reversible process, the colloid returning by evaporation to its original condition, and it therefore follows that Clausius' equations can be applied in this case as well as in the expansion of bodies by heat.

Rodewald[1] has done this in the case of starch, and has calculated from the results its internal pressure, which was found to vary from 2073 kilos. per sq. cm. in dry starch to 561 kilos. in starch fully saturated with aqueous vapour. He also calculated from its vapour-pressure its molecular weight in the solid form as 4370, closely corresponding to twenty-seven times the empirical formula $C_6H_{10}O_5$. This is interesting as derived in a different way from the molecular weight determinations in liquids. The method is obviously applicable to other solid colloids.

The pressures exerted in the early stages of colloid swelling are very large, though they become almost inappreciable as the maximum is approached. The ancient use of dry wood wedges subsequently moistened is an instance of this, and it may be mentioned that stones of the trilithon at Baalbec in Syria, weighing over 1,000 tons, have obviously been split in this way. The effect has usually been ascribed to capillary contraction, but a little consideration will show that capillarity cannot produce expansive effects. A pile of thin plates (*e.g.*, cover-glasses on the microscope stage) will be compressed and not expanded if water is allowed to be drawn between them by capillarity. The effect is necessarily molecular and osmotic, the liquid getting *within* the sphere of molecular attractions, and so sustaining and liberating for expansion a portion of the enormous internal pressures which have just been mentioned (in the case of starch some 1,500 atmospheres).

The point of maximum swelling, whether in liquid or vapour, is obviously a definite equilibrium which is reached when the attraction of the colloid for the liquid or vapour is balanced by the internal attractions of the colloid and the liquid in themselves. The liquid and the colloid are in complete osmotic equilibrium, and consequently, according to a well-known law, are both in equilibrium with the vapour. P. von Schroeder[2] draws attention to an apparent exception to this law, which is of considerable importance, and for which he was unable to offer a satisfactory explanation. He found that agar and gelatine jellies swelled to a considerably larger extent when immersed in water than they did in saturated aqueous vapour, and that when the jelly, saturated by immersion, was suspended in saturated vapour it dried till it was again in equilibrium with the vapour; thus evidencing a greater vapour-pressure than the liquid water with which it was in osmotic equilibrium. He found, however, that when the jelly was swollen with an N/100000 solution of a sulphate instead of water, no contraction, but slight further swelling, occurred; while an N/1000000 solution diminished but did not prevent the evaporation. As the $N/10^5$ solution may be assumed to be completely ionised it will contain three gram-ions in 2×10^8 c.c., and at 0° C. will exert an osmotic pressure of 340 dynes per cm.^{2}. This would involve work of 340 ergs per gram of water removed, and would correspond to raising a gram of water only 0·344 cm. in height, but Von Schroeder took special precautions to avoid difference in level. If, however, a portion of water is removed from the mass, the surface is extended and work is done (on the assumption of spherical form) of 370 ergs per gram. The surface-tension is less, and the osmotic pressure greater, at laboratory temperature (about 365 dynes at 20°), so that the

[1] *Z. f. Phys. Ch.*, 1897, **24**, 193; and *Untersuchungen über die Quellung der Stärke*, Lepsius and Fischer, Leipzig, 1896.

[2] *Ibid.*, 1903, **45**, 75–117.

energy of surface-tension agrees well with that found to produce the effect, and is a sufficient cause. The figures are perhaps less important as explaining an apparent anomaly than as illustrating the smallness of the forces involved in considerable changes of volume near the maximum swelling. The relation of surface-tension to the drying of gels consisting of aggregates of particles, as that of silica, may be here again referred to. If the common tension between the surfaces of the particles is less than that of water itself, as in gels is necessarily the case, they will retain a large amount of water by surface attraction, the vapour-pressure of which will be equal to or somewhat less than that of liquid water according to the tenuity of the film. As the water is removed by evaporation the particles will cohere by their mutual attraction, and if this cohesive attraction is greater than the difference between the tension of water and that of the common surface, or, in other words, than the difference between the attraction of the particles for water and the attraction of water for itself, water will not again spread between the particles, and the drying will be irreversible as in the earlier stages of the silica jelly.

The rate of absorption of liquid by solid colloids has been studied by Hofmeister[1] and more recently by Pauli (Pascheles).[2] The latter showed, both mathematically and by experiment on agar and gelatine, that if Q be the degree of swelling and M its mass, the rate of swelling $\frac{dQ}{dt}$ at any given time is equal to $(M-Q)C$, the difference between the actual and the maximum swelling multiplied by a constant, which varies with the material and probably with the temperature. This is a law common to many chemical and physical changes, but complicated in this case by the constantly increasing thickness of the swelling colloid. For very thin plates, where this can be neglected, and between the times t and t_1 and the swelling Q and Q_1 the constant $C = \frac{1}{t_1 - t} \ln. \frac{M-Q}{M-Q_1}$, and for agar is about $9{\cdot}5 \times 10^3$.

The swelling of gelatine jelly is much influenced by acids and alkalies, both of which largely increase alike its amount and its rapidity. The action of neutral salts on swelling, as regards gelatine, has been investigated by Hofmeister;[3] their effect on melting and gelatinising temperatures by Pauli,[4] and on viscosity by von Schroeder All these effects are practically parallel; salts which lessen swelling raise the melting-point of jellies and increase the viscosity of the sols. The effect seems an additive one in which anions and cations take part, but no definite laws have been established. The order of the salts investigated, placing those first which most raise the melting-point, is sulphates, citrates, tartrates, acetates, water, chlorides, chlorates, nitrates, bromides, iodides as anions; and K, Ca, Na, Sr, and Mg as cations; those placed before water raising, and those after it lowering, the melting-point. Whether the same order applies to other colloids than gelatine is uncertain, but no doubt the effects depend to a considerable extent on the specific affinities of salt and colloid.

The swelling, though mainly an osmotic effect, is influenced by the solid cohesion of the jelly, and there can be little doubt that at the moment of setting a network is formed, whether molecular or coarser,

[1] *Archiv f. exp. Path. und Pharm.*, 1890, **27**, 395–413. [2] *Ibid.*, 1895, **36**, 100.
[3] *Ibid.*, 1891, **28**, 210–238. [4] Pfluger, *Archiv*, 1898, **71**, 1–24.

which remains intact during the existence of the jelly. Experiments made by the writer show that the volume of the jelly at the moment of setting has considerable effect on the maximum of swelling, though concentrated jellies after drying swell in water to more, and dilute to less, than their original volume. A solution originally containing 23 grm. of water reabsorbed 14·5 grm., one of 11 grm. 7·8 grm, and one of 5 grm. 6 grm. per grm. of dry gelatine. If weak jellies are mechanically squeezed a considerable amount of liquid, mostly water, can be expressed, and this has been used as an argument for the cellular (two-phased) structure of jellies. It is obvious, however, that near the swelling maximum this must be possible in any case, since it has been already shown that considerable changes of volume can be produced by changes of osmotic pressure equivalent to less than 1 cm. of water.

The phenomenon of 'semipermeability' is frequently exhibited by colloid gels and jellies. and, in fact, all the usual semipermeable membranes are colloidal. Just as solids will dissolve in one solvent, and not in another, so jellies are selective in the liquids which they will absorb. Indiarubber will absorb hydrocarbons but not water; gelatine and agar, water but not hydrocarbons or alcohol; and the process of transfusion in a semipermeable membrane is not one of mere mechanical filtration of a finer order, but of absorption and solution on one side of the membrane, and solution and diffusion on the other, and is intimately connected with the chemical character of the membrane and with its ionic charge. Colloid jellies or membranes are usually impermeable to other colloids, while most dissolved salts diffuse in them with nearly the same rapidity as in pure water, though they are sometimes semipervious to those containing a common ion. In dilute jellies, however, some diffusion of finely divided colloids takes place; and Bechhold[1] has used dilute jellies (under pressure, supported on coarser media) for the fractional filtration of colloid solutions. Gelatine and gelatinous membranes are semipermeable to alcohol, which exerts considerable osmotic pressure in a gelatine-lined cell, and jelly is easily dehydrated in absolute alcohol till it contains less than its own weight of water, very little alcohol diffusing into the jelly. On the other hand, if alcohol is mixed with a warm gelatine solution in insufficient quantity to cause precipitation and is allowed to set, the jelly will show much more than its normal maximum swelling when immersed in water, from the osmotic pressure of the contained alcohol which cannot escape. This observation proves clearly that the contraction is not due to any chemical action of the alcohol, but to simple osmotic causes. If alcohol in sufficient quantity be added to a warm and ungelatinised solution of gelatine, it causes separation of the latter, first as a milky liquid, which rapidly flocculates, and, if stirred, coheres into a solid mass, thus showing all the usual phenomena of coagulation, from what are obviously purely osmotic causes. Similar effects occur with gums, dextrine, and most other water-soluble colloids. With egg-albumen the coagulation is irreversible, but in most cases re-solution takes place on again substituting water.

Dilute acids and alkalies greatly raise the maximum swelling of gelatine and all gelatinous animal tissues such as skin. French gelatine with a maximum absorption of seven to eight times its weight of water will absorb over fifty times in hydrochloric acid of 0·003 grm.-mol. per litre, at about

[1] Vortr. 78. *Vers. d. Naturf. u. Aerzte*, Stuttgart, 1906.

which concentration the swelling reaches a maximum, falling gradually to below twenty times at 0·4 grm.-mol. per litre, much beyond which the experiment cannot be carried because of solution of the jelly in the acid. Similar effects occur with all other acids which the writer has investigated in which a sufficient concentration can be employed without causing solution. The concentration of the acid in the swollen jelly is always greater than in the external solution, increasing (in the case of gelatine at least) somewhat rapidly at first, before the maximum of swelling is reached, and later remaining nearly constant at 0·002 or 0·003 mol. per litre above the outside solution; while the total quantity of absorbed acid per grm. of gelatine increases by a law very approximately exponential. The whole of the hydrochloric acid can be estimated by titration with caustic alkali in presence of phenolphthalein, but only a portion with methyl orange, showing that one part of the acid exists in a less ionised state than the remainder. The swollen jelly can no longer be dehydrated by absolute alcohol, showing that the osmotic pressure of water into the jelly is now greater than that into the alcohol, but a part of the acid, approximately corresponding to that estimated by methyl orange, can be removed by repeated treatment with alcohol. The jelly is still pervious to acid and salt solutions, though probably to a less extent than neutral jelly, and it is obvious that one portion of the acid exists in some sort of combination with the jelly, while another is merely osmotically absorbed. It is clear that no definite conclusions can be drawn until in some way these portions can be distinguished; and as a first approximation (obviously not quite correct) it was assumed that the acid absorbed in swelling was of the same concentration as that of the outer solution, the less ionised and more constant portion, which may be called 'fixed acid,' being ascertained by subtracting the calculated value of the acid in the absorbed liquid from the total found in the jelly. The result showed that the 'fixed acid' rapidly reached a maximum coincident with the concentration of maximum swelling, after which it remained approximately constant, a slight downward curve being probably due to the inaccuracy of the assumption that the strength of the absorbed solution was equal to that outside, or, what amounts to the same thing, that the whole of the water in the jelly was present as absorbed outer solution. With a small correction in this sense the amount of 'fixed acid' obtained in this way closely corresponds to that not estimated by phenolphthalein, and incapable of being washed out by alcohol. From inspection of the curves it is obvious that that of total acid per grm. of gelatine is of an exponential type, but it is compounded of that of 'fixed acid' the character of which strongly suggests chemical combination somewhat complicated by dissociation or hydrolysis; and of the curve of swelling, which after its maximum is reached, is of a hyperbolic character. If, as is probable from the empirical formula, the molecular weight of gelatine is about 1800, or its multiple, it would roughly correspond to the fixation of two mols. of HCl by one of gelatine.

The action of salts on unacidified gelatine has been mentioned, and common salt causes a small increase of swelling as compared with water, and even saturated solutions have no dehydrating effect. If, however, salt is added to jelly swollen with hydrochloric acid, swelling is immediately reduced, and very powerful dehydration comparable with that of absolute alcohol is obtained by saturated salt solutions in presence of the amount of acid necessary to the maximum swelling effect. At the same time the total acid in the jelly is diminished, but the 'fixed acid' is gradually, though not largely, increased. It is probable that if the concentration of the hydrochloric acid could be increased to an equal extent to that of the salt without causing solution an equal dehydration would be produced, and it is difficult to resist the conclusion that the swelling is due to the chlorine ion in the acid gelatine, and is osmotically repressed by the increase of the same ion in the solution. Other acids with their neutral salts produce similar effects. The fact that similar dehydration is produced by other acids, *e.g.*, sulphuric, in conjunction with sodium chloride, and probably with other salts, does not contradict the conclusion that it is the common anion which is operative, since in the case suggested an equilibrium of sodium and gelatine sulphates and sodium and gelatine chlorides would result. The cause of the general swelling effect of acids must, however, in some way be intimately connected with their common H ion, and that of alkalies, which is equally powerful, with the hydroxyl ion. The alkaline swelling is not repressed by sodium chloride, even when caused by sodium hydrate, but is repressed by sufficient concentration of the hydroxyl ion in the outer solution. The above are the summarised results of a research on which the writer has been some time engaged, and which he hopes shortly to publish with a more detailed discussion of the operating causes. It may be remarked that the dehydration of acidified gelatinous tissues has an important technical application in the preservation of sheep pelts by 'pickling' with salt and sulphuric acid, and its bearing on mineral tannages in which salt is employed with alums and other compounds of acid reaction is very obvious. As gelatine is decidedly amphoteric, and is known to be capable of decomposing many salts in solution, it is quite possible that some of the complicated effects of unacidified salt solutions which have been referred to may be due to partial absorption of the acid of the salt and the osmotic effect of the remainder on the compound formed.

Space will not allow of any detailed discussion of the coagulation of the various albumins by heat and precipitating agents, which, important as they are from the physiological aspect, have not yet yielded many facts which can be explained on general principles. Albumins, carefully freed from electrolytes by dialysis, are electrically neutral and incompletely coagulated by heat or by those precipitants which do not at the same time communicate an electrical charge. The addition of a trace of acid which gives a positive charge renders them liable to complete coagulation by heat and much more sensitive to the action of electrolytes; but larger quantities of acid, perhaps by producing soluble acid-albumins, prevent coagulation. Traces of alkalies which give a negative charge have a similar effect, though the precipitation is usually less complete, and excess again prevents or lessens precipitation. Coagulation by heat is usually irreversible, and so also that by alcohol, though zymases are precipitated by the latter in a reversible (soluble) form. Salts of the heavy metals, even in small quantities, produce irreversible coagulation, very possibly connected with combination, or colloidal precipitation with a colloidal compound of the metal. Excess of the precipitant frequently prevents precipitation, probably by the formation of new complex compounds. Possibly there may be some connection between these phenomena and the irreversible (tanning) effects of some metallic solutions on gelatinous tissues. These solutions are usually of 'basic salts' containing metallic oxides colloidally dissolved. Precipitations of albumins by alkali salts, especially in neutral solution, are generally reversible.[1]

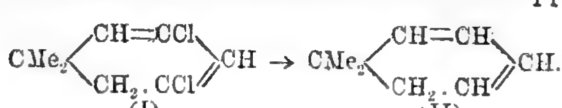
The relations of colloid chemistry to technology can here only be briefly alluded to. The industries of indiarubber, gutta-percha, gums, dextrine, glue and gelatine, and cellulose derivatives are of course all colloidal, and it is probable that many reactions which have been described as chemical may really be those of absorption compounds. Tanning and dyeing are particularly concerned with the mutual precipitation of colloids and that by inorganic reagents, and in these industries also the distinction between physical and chemical reactions in any given case is one of extreme difficulty, which is much accentuated by the want of any method for the separation of colloids comparable with crystallisation, or even fractional distillation.

Among industries with inorganic colloids may be mentioned the comparatively new one of the manufacture of colloid fibres for electric glow-lamps from difficultly fusible metals, and both earthenware and agriculture are largely dependent on the properties of colloidal suspensions. Glass manufacture is also a colloid industry, and coloured glasses solid colloidal solutions; and modern pigments are largely colloidal precipitates and colour-lakes.

In conclusion it is only right to acknowledge indebtedness to the excellent work of Dr. Arthur Müller, 'Allgemeine Chemie der Kolloide,'[2] with its extensive bibliography; and to the 'Zeitschrift für Chemie und Industrie der Kolloide,' edited by Dr. Wolfgang Ostwald, without which the preparation of such a report would have been extremely laborious. Owing to the very numerous and often somewhat inaccessible journals in which important work has appeared, it has been necessary in many cases to trust to abstracts, and it is possible that from this cause full justice has not been done to some authors.

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 : 1-*Dimethyl-*$\Delta^{2:4}$*-dihydrobenzene and* 1 : 1-*dimethyl-*$\Delta^{2:5}$*-dihydrobenzene.*[3]—An account of the preparation of 1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene (II) by the reduction of 3 : 5-dichloro-1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene (I) with sodium in moist ethereal solution appeared in 1902.[4]



(I) (II)

Shortly after the publication of this work, Harries and Antoni[5] expressed doubt, not only as to the constitution but also as to the composition of this hydrocarbon. Their criticisms were, in part, answered

[1] The work of Cohnheim, *Chemie der Eiweisskörper*, 1904, and of Pauli and Spiro in the *Beitr. z. Chem. Phys. und Path.* from 1903 onwards seems specially worthy of attention. [2] J. A. Barth, Leipzig, 1907.

[3] Crossley and Renouf, *J.C.S.*, 1908, **93**, 629.

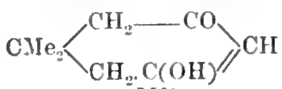
[4] Crossley and Le Sueur, *J.C.S.*, 1902, **81**, 821. [5] *Annalen*, 1903, **328**, 88.

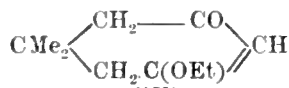
at the time,[1] but it was considered desirable to try to prepare the substance by another method, in the hope that a comparison of the two specimens of the hydrocarbon would throw further light on the problem. This has now been done, with the result that the correctness of the earlier experiments and deductions are completely confirmed, allowing the following conclusions to be arrived at :—

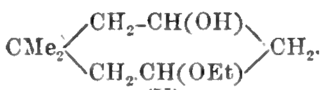
1. The dimethyldihydrobenzene described by Crossley and Le Sueur is 1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene, containing as impurity a very small amount of some oxygenated substance, probably a methoxy- compound.

2. The hydrocarbon described in this report (dimethyldihydrobenzene C and R),[2] and prepared by the elimination of two molecules of hydrogen bromide from dibromodimethylhexahydrobenzene, is a mixture, in approximately equal quantities, of pure 1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene and pure 1 : 1-dimethyl-$\Delta^{2:5}$-dihydrobenzene.

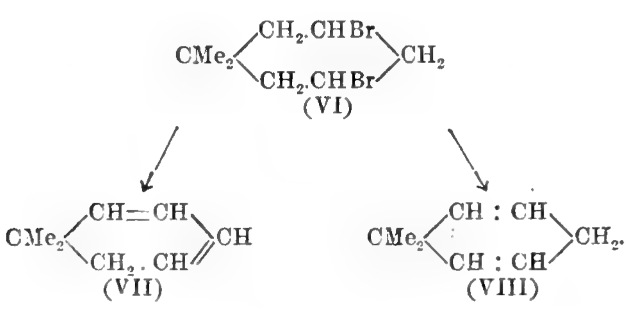
The starting-point in the synthesis was again dimethyldihydroresorcin (III), which was first converted into its ethyl ether (IV),[3] and this by reduction with sodium in absolute ethyl-alcoholic solution into 3-hydroxy-5-ethoxy-1 : 1-dimethylhexahydrobenzene (V) :—


(III)


(IV)


(V)

The ethoxy- compound gives with fuming hydrobromic acid dibromodimethylhexahydrobenzene (VI), which when treated with quinoline loses readily and completely two molecules of hydrogen bromide, with formation of dimethyldihydrobenzene, and this reaction takes place in two ways, giving rise to 1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene (VII), or to 1 : 1-dimethyl $\Delta^{2:5}$-dihydrobenzene (VIII) : in approximately equal amounts.


(VI) (VII) (VIII)

[1] *Ber.*, 1903, **36**, 2692.

[2] To avoid confusion as far as possible, the hydrocarbon described in this report, which is a mixture of pure 1 : 1-dimethyl-$\Delta^{2:4}$ dihydrobenzene and of pure 1 : 1-dimethyl-$\Delta^{2:5}$-dihydrobenzene, is referred to as dimethyldihydrobenzene (C and R), the 1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene, prepared by Crossley and Le Sueur, as dimethyldihydrobenzene (C and S), and the supposed 1 : 1-dimethyl-$\Delta^{2:5}$-dihydrobenzene of Harries and Antoni (*loc. cit.*) as dimethyldihydrobenzene (H and A).

[3] *J.C.S.*, 1899, **75**, 775.

The following is a tabulated comparison of the properties of this hydrocarbon with those of the dimethyldihydrobenzene prepared by Crossley and Le Sueur :—

	Dimethyldihydrobenzenes	
	(C and S)	(C and R)
B. p.	111°	111·2°
Sp. gr. at 15°/15°	0·8153	0·8147
Index of refraction	1·4548	1·4535
Molecular refraction	60·217	60·251
Magnetic rotation	11·024	10·450
Colour with H_2SO_4	Blood-red turning to violet-purple	Blood-red turning to violet-purple
Fuming HBr	Monohydrobromide, b. p. 90·5°/36 mm.	Monohydrobromide, b. p. 83°/20 mm. Dihydrobromide, b. p. 137°/25 mm.
Bromine	Dibromide, unstable liquid	Dibromide, unstable liquid Tetrabromide, m. p. 102°
NOCl	Nitrosochloride, m. p. 121°	Nitrosochloride, m. p. 121°
Nitrating mixture	No definite product	Trinitro-*o*-xylenes, m. p. 71° and 115°
Oxidation products	*as*-dimethylsuccinic acid	*as*-dimethylsuccinic acid, dimethylmalonic acid
Oxidation products of monohydrobromide	*as*-dimethylsuccinic acid, ββ-dimethylglutaric acid, lactone of α-hydroxy-ββ-dimethylglutaric acid	*as*-dimethylsuccinic acid, ββ-dimethylglutaric acid, lactone of α-hydroxy-ββ-dimethylglutaric acid

From the above table the most important chemical properties of dimethyl-$\Delta^{2:4}$-dihydrobenzene and dimethyl-$\Delta^{2:5}$-dihydrobenzene would appear to be :—

1 : 1-Dimethyl-$\Delta^{2:4}$-dihydrobenzene	1 : 1-Dimethyl-$\Delta^{2:5}$-dihydrobenzene
Hydrobromide, $C_8H_{13}Br$, b. p. 83°/20 mm. Nitrosochloride, m. p. 121° Dibromide, $C_8H_{12}Br_2$, unstable liquid No nitro-derivatives obtainable Oxidation product, *as*-dimethylsuccinic acid	Hydrobromide, $C_8H_{14}Br_2$, b. p. 137°/25 mm. No nitrosochloride isolated Tetrabromide, $C_8H_{12}Br_4$, m. p. 102° Trinitro-*o*-xylenes, m. p. 71° and 115° Oxidation product, dimethylmalonic acid

The criticisms of Harries and Antoni (*loc. cit.*) may then be replied to as follows.

In the first place, these authors consider that the analyses given by Crossley and Le Sueur (*ibid.*) are midway between those for a dimethyldihydro- and a dimethyltetrahydro-benzene. The mean of the two analyses quoted gave C=88·30 and H=11·27, and it is obvious from the

Difference	Calculated C_8H_{14}	Found	Calculated C_8H_{12}	Difference
+ 1·03	87·27	C = 88·30	88·88	− 0·58
− 1·46	12·73	H = 11·27	11·11	+ 0·16

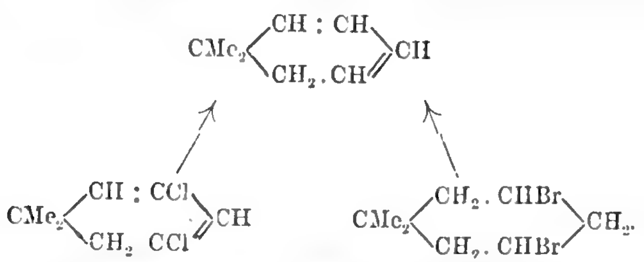
annexed comparison that the numbers do not lie midway between the calculated figures, the differences in those found and calculated for C_8H_{14} being very large, and the errors in the wrong direction; for as a rule carbon is found too low and hydrogen too high and not *vice versa.* Moreover, if any appreciable quantity of dimethyltetrahydrobenzene had been present it could hardly have escaped detection, as on oxidation it would have yielded $\beta\beta$-dimethyladipic acid, which presents no difficulty of isolation or identification.

If the above quoted figures for dimethyldihydrobenzene (C and S) are examined, it will be found that they add up to 99·57; and it is considered most probable that the discrepancy is due to oxygen present in the form of traces of a methoxy- compound.

Another suggestion made by Harries and Antoni is that dimethyldihydrobenzene (C and S) is not a true dihydrobenzene but contains a trimethylene ring as represented in formula IX. Altogether apart from the probable incapability of existence of such a body, it may be

(IX)

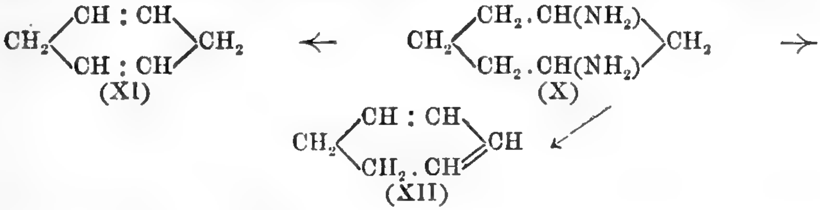
mentioned that the magnetic rotation of the hydrocarbon would have at once proved the presence of a trimethylene ring, and, moreover, there is now evidence that the same dimethyldihydrobenzene is produced by the reduction of dichlorodimethyldihydrobenzene, and by the removal of the elements of hydrogen bromide from dibromodimethylhexahydrobenzene.



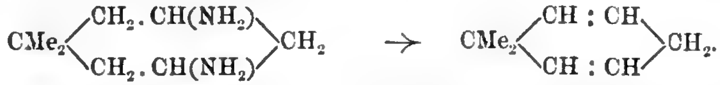
This can only be explained if the substance be designated 1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene, and hence the possibility of a trimethylene ring being present in the hydrocarbon is precluded.

The whole question is further complicated by the fact that Harries and Antoni prepared a hydrocarbon, which they believed to be 1 : 1-dimethyl-$\Delta^{2:5}$-dihydrobenzene also from dimethyldihydroresorcin as a starting-point; but, unfortunately, no information is given as to any derivatives which would enable a comparison to be made with the hydrocarbon having that undoubted structure described in this report; and it would appear that the present evidence is insufficient definitely to establish the constitution of Harries and Antoni's hydrocarbon. The single piece of evidence on which the supposed constitution of this latter substance is based is oxidation, whereby oxalic, a succinic, and malonic acids were obtained, none of which bodies afford any direct proof that the hydrocarbon contained the *gem*-dimethyl group.

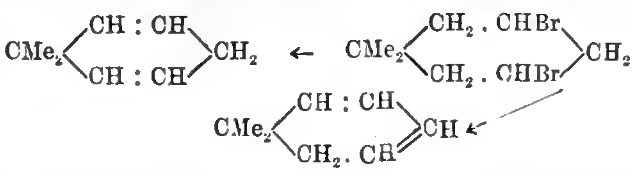
Nor is there any apparent reason for supposing that the elimination of ammonia from the cyclic diamine would take place in one way and one way only. Harries and Antoni have themselves shown that, when the phosphate of diaminohexahydrobenzene (X) is submitted to dry distillation, ammonia is evolved in both of the possible directions, giving rise to a mixture of $\Delta^{1:3}$-dihydrobenzene (XI) and $\Delta^{1:4}$-dihydrobenzene (XII)



and they therefore conclude that 'the *gem*-dimethyl group influences the position taken up by the double bonds,'



If this is so, why does it not influence the position of the double bonds when hydrogen bromide is eliminated from dibromodimethylhexahydrobenzene? For this is a reaction strictly analogous to the



reaction used by Harries and Antoni, and yet it takes place in both ways, giving rise to a mixture of the two possible hydrocarbons in equal amounts. The presence of the *gem*-dimethyl group certainly does not exercise any apparent influence in this case, nor in the position of the double bond formed when 3-bromo-1 : 1-dimethylhexahydrobenzene loses the elements of hydrogen bromide.[1]

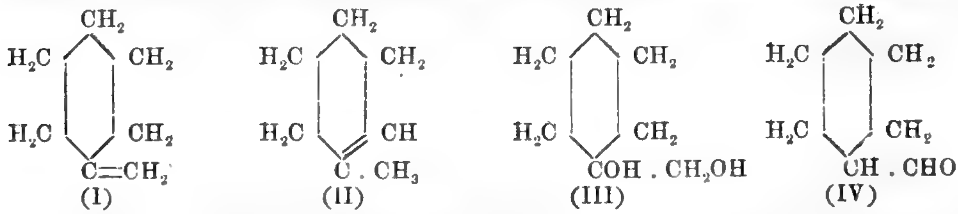
Harries and Antoni state that 2 grams of their dimethyldihydrobenzene gave, on treatment with a nitrating mixture, 0·6 gram of trinitro-*m*-xylene, which might be regarded as a proof that dimethyldihydrobenzene (H and A) does not contain the *gem*-dimethyl group, for though many cases of the wandering of a methyl group in derivatives of *gem*-dimethyldihydroresorcin have been recorded,[2] no single instance has been observed in which a methyl group has wandered into anything but an ortho- position. Moreover, dimethyldihydrobenzene (C and R) undoubtedly contains dimethyl-$\Delta^{2:5}$-dihydrobenzene, and under the influence of a nitrating mixture it is this hydrocarbon which is converted into the two possible trinitro-*o*-xylenes.

Recent Work on Hydro-aromatic Substances.

Hydrocarbons.—Methylenecyclohexane (I) has been submitted to detailed investigation by Faworsky and Borgmann,[3] who conclude that the hydrocarbons of this supposed constitution, previously described by Sabatier, Wallach, and Zelinsky and Gutt, are in reality mixtures of methylenecyclohexane and 1 : methyl-Δ^1-tetrahydrobenzene (II). For the preparation of the pure hydrocarbon cyclohexylcarbinol, obtained by

[1] *J.C.S.*, 1906, **89**, 1556. [2] *Ibid.*, 1904, **85**, 264; 1906, **89**, 875.
[3] *Ber.*, 1907, **40**, 4863.

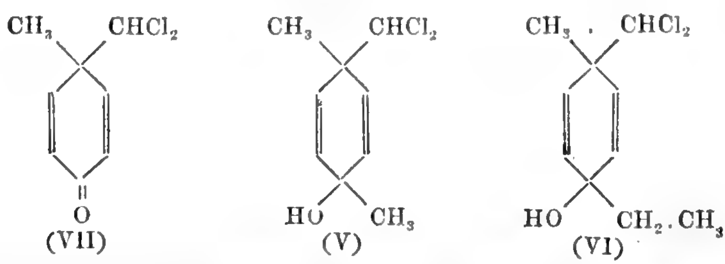
the Grignard reaction from bromohexahydrobenzene, was converted into the corresponding iodide, and this latter body heated with alcoholic potash.



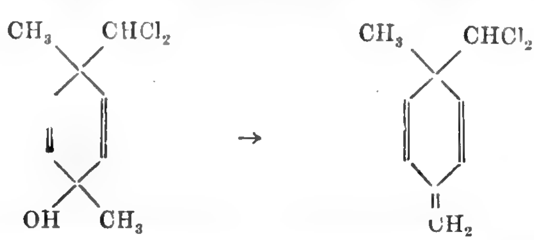
Methylenecyclohexane absorbs two atoms of bromine, and the resulting dibromide gives, on warming with 10 per cent. potassium carbonate solution, the glycol having formula III. When treated with very dilute sulphuric acid this glycol gives an aldehyde (IV), which can also be obtained directly from the dibromide by treatment with lead oxide and water. These facts conclusively prove the constitution of the dibromide and of the hydrocarbon.

Methylenecyclohexane is unaltered on boiling with quinoline, but is converted by a mixture of quinoline and quinoline-hydriodide into the isomeric methyltetrahydrobenzene (II). This fact would account for the hydrocarbon obtained by Zelinsky and Gutt from the iodide of cyclohexylcarbinol by heating with quinoline, being a mixture of the two isomerides.

Auwers[1] has shown that the alcohols V and VI, prepared from the ketone VII by Grignard's reaction, lose water to give unstable intermediate products, which readily pass into benzene derivatives. These reactions



have been very fully investigated, and are described in detail in this lengthy memoir. The hydroaromatic alcohols V and VI and their homologues are not very stable substances, and many, if not all, exist in two modifications, probably due to *cis-* and *trans-*isomerism. The above-mentioned intermediate products are considered to be alkylidenedihydrobenzenes,

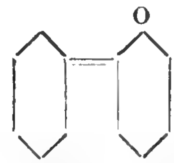


the general chemical and physical properties of which substances are

[1] *Annalen*, 1907, **352**, 219, 273, 288.

discussed, compared with other closely related compounds, and shown to support the above conclusions as to their constitution.

Ketohexahydrobenzene is acted on by dry hydrogen chloride [1] to give a substance having the formula $C_{12}H_{19}OCl$, which loses the elements of hydrogen chloride to give cyclohexene-2-cyclohexanone.



When this dicyclic ketone is reduced it yields the corresponding saturated alcohol, and this, by treatment with hydrogen iodide, the fully hydrogenised dicyclohexyl $C_6H_{11}.C_6H_{11}$.

Alcohols.—Aromatic quinones [2] give, when treated with hydrogen in presence of reduced nickel, a variety of products, the nature of which depends largely on the reaction temperature; if moderately low the dihydric alcohols of the hexahydrobenzene series are formed.

Monohydric alcohols may be obtained [3] by the action of various alkyl magnesium iodides on ethyl hexahydrobenzoate. The latter is readily prepared by treating cyclohexylmagnesium iodide with carbon dioxide.

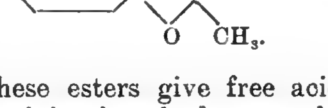
Ketones.—The action of light on ketohexahydrobenzene and the three isomeric ketomethylhexahydrobenzenes has been studied by Ciamician and Silber,[4] who find that the ring is broken with production of a fatty acid containing the same number of carbon atoms together with the corresponding unsaturated aldehyde.

Not only ketohexahydrobenzene itself,[5] but also a number of other simple ring ketones, such as ketomethyl- and ketomethylisopropylhexahydrobenzene are found to be capable of reacting in the enolic form.[6]

The influence of a very reactive agent, for example acetic anhydride, is necessary to bring about the change and the resulting acetates are converted on saponification into the original ketones.

Homologues of ketohexahydrobenzene may be prepared [7] by the slow distillation of the anhydrides of substituted pimelic acids.

Ketohexahydrobenzene and the three isomeric ketomethylhexahydrobenzenes condense with ethyl α-chloropropionate [8] in presence of sodium ethoxide, to the corresponding glycidic esters, the product in the first case having the formula

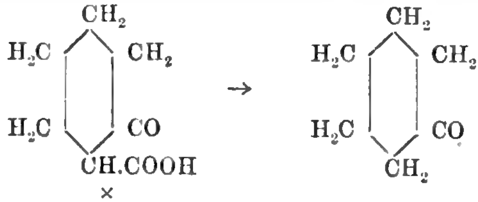


On saponification these esters give free acids, which decompose on distillation in a vacuum giving hexahydroacetophenone or its homologues. This latter ketone is, however, best prepared [9] by treating the magnesium compound of cyclohexyliodide with acetaldehyde, and oxidising the

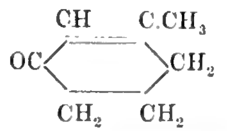
[1] Wallach, *Ber.*, 1907, **40**, 70.
[2] Sabatier and Mailhe, *Compt. rend.*, 1908, **146**, 457.
[3] Hell and Schall, *Ber.*, 1907, **40**, 4162.
[4] *Reports*, 1907, 110.
[5] *Ber.*, 1908, **41**, 1071.
[6] Mannich and Hänen, *Ber.* 1908, **41**, 564.
[7] Blanc, *Compt rend.*, 1907, **144**, 1356.
[8] Darzens, *Compt. rend.*, 1907, **144**, 1123.
[9] Hell and Schall, *Ber.*, 1907, **40**, 4162.

resulting methylcyclohexylcarbinol $C_6H_{11}.CHOH.CH_3$ with chromic acid.

In the preparation of ketones by elimination of carbon dioxide from ketocarboxylic acids Kötz[1] finds that the reaction takes place readily in the case of 1-ketohexahydrobenzene-2-carboxylic acid, but it does not proceed at all with acids and less readily with alkalis, as the hydrogen atom marked with a × is replaced by methyl, ethyl, or isopropyl.

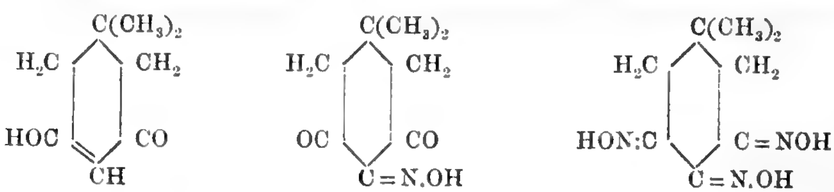


1-keto-3-methyl-Δ^2-tetrahydrobenzene[2]



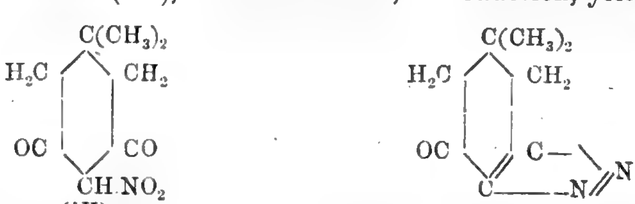
exists in two isomeric forms, which must have the same structure, as on oxidation with potassium permanganate both yield γ-acetobutyric acid. The molecular refraction would lead to the conclusion that both are doubly unsaturated alcohols and not ketonic in nature. Chemically the two forms are identical except in their behaviour towards ferric chloride, when the one gives a pale wine-red colour, whereas the other becomes violet. The present data do not suffice to explain this case of isomerism.

Dimethyldihydroresorcin (I) reacts towards nitrous acid as a di-



(I) (II) (III)

ketone,[3] for the resulting isonitrosodimethyldihydroresorcin (II) reacts with two molecular proportions of hydroxylamine to give a compound of formula III. Oxides of nitrogen convert dimethyldihydroresorcin into the nitro-derivative (IV), which substance, on reduction, yields an amine,

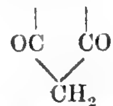


(IV) (V)

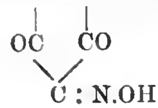
and this gives with nitrous acid a compound whose constitution may be represented by formula V. The relation of colour to constitution in

[1] *Annalen*, 1907, **357**, 192.
[2] Rabe, *Ber.*, 1907, **40**, 2482.
[3] Haas, *J.C.S.*, 1907, **91**, 1433.

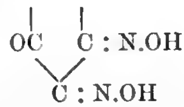
these compounds is somewhat striking. Thus, while dimethyldihydroresorcin



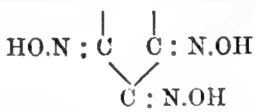
is colourless, isonitrosodimethyldihydroresorcin



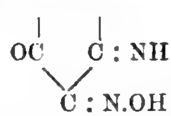
is yellow; its potassium and ferrous salts are deep blue, and its ammonium salt violet: the monoxime



is colourless, but dissolves in alkalis to a yellow solution, and gives with ferrous sulphate a deep azure blue. The dioxime

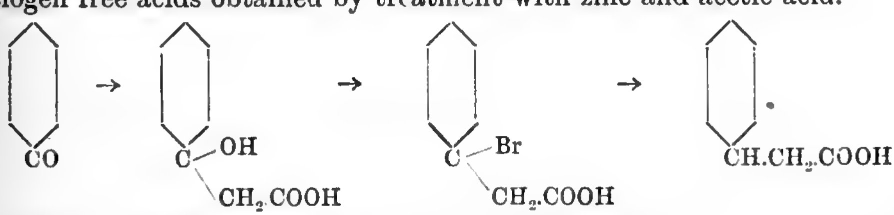


on the other hand, is greyish pink, but gives a yellow solution in caustic alkalis, and produces with ferrous sulphate a violet colour. Replacement of one of the carbonyl oxygen atoms in isonitrosodimethyldihydroresorcin by the imino group



changes the colour from yellow to deep violet; the potassium salt of this compound is magenta, while the ferrous salt is deep blue.

Acids.—A number of carboxylic acids of the hydroaromatic series have been synthesised by Wallach [1] by condensing cyclic ketones with ethyl bromoacetate. The hydroxyl group in the resulting esters is replaced by bromine through the agency of hydrogen bromide, and the halogen free acids obtained by treatment with zinc and acetic acid.

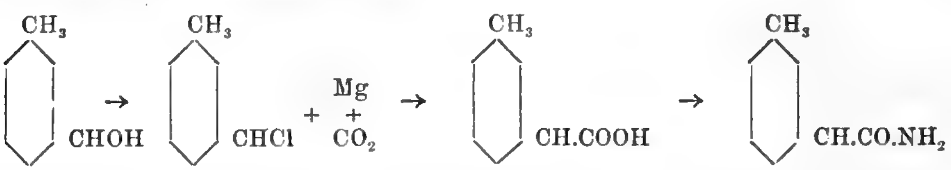


Skita [2] concludes from a study of ethyl 4-amino-2 : 6 : 6-trimethylhexahydrobenzene-1-carboxylate, prepared from ethyl isophoronecarboxylate, that hydroaromatic amino- acids show *cis-trans*-isomerism; that they are similar in their chemical behaviour to the aliphatic amino-acids, and also physiologically, in that they possess the property of producing local anæsthesia.

Amines.—Gutt [3] has prepared hexahydrobenzylamine and the five

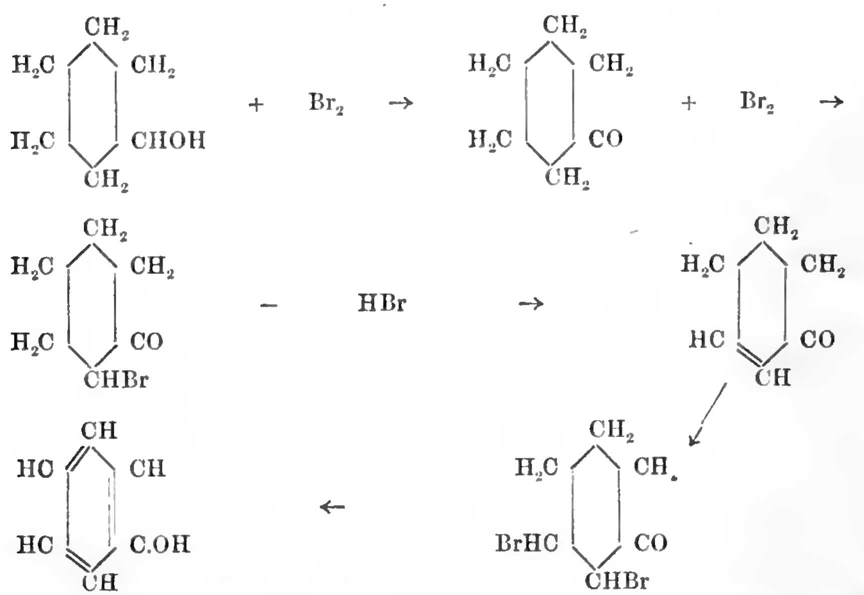
[1] *Cent. Blatt.*, 1907, ii. 52. [2] *Ber.* 1907, **40**, 4167. [3] *Ibid.*, 1907, **40**, 2061.

theoretically possible aminomethylhexahydrobenzenes, which are easily characterised by the melting-points of their benzoyl derivatives. The preparation is realised as follows:—



On treatment with bromine in presence of sodium methoxide the amide gives a urethane, which on distillation with lime yields the amine.

Aromatic from Hydro-aromatic Substances.—Kötz and Götz[1] have studied the action of chlorine or bromine on hydroxyhexahydrobenzene and on hexahydrosalicylic acid, and have isolated a number of products intermediate between the fully saturated hydro-aromatic bodies and the corresponding aromatic derivatives. An indication of the course of the various reactions may be gleaned from the following scheme:—



Reference may also be made to the following papers, which contain a description of many interesting hydro-aromatic substances: 'Hydro-aromatic Sulphur Compounds,'[2] 'Hydrophthalic Acids,'[3] 'Synthesis of Alcohols of the Hexahydrobenzene Series,'[4] 'Derivatives of Phenylcyclohexane,'[5] 'Hexahydrobenzaldehyde.'[6]

[1] *Annalen*, 1908, **358**, 183.
[2] Borsche and Lange, *Ber.*, 1907, **40**, 2220.
[3] Abati, *J.C.S.* Abst., 1907, **1**, 419, 420.
[4] Sabatier and Mailhe, *Ann. Chim. Phys.*, 1907 (8), **10**, 527.
[5] Kursanow, *J.C.S.* Abst., 1907, **1**, 599.
[6] Zelinsky and Gutt, *Ber.*, 1907, **40**, 3050, 3055.

The Excavation of Critical Sections in the Palæozoic Rocks of Wales and the West of England.—Report of the Committee, consisting of Professor C. LAPWORTH (*Chairman*), Mr. G. W. FEARNSIDES (*Secretary*), Mr. J. LOMAS, Dr. J. E. MARR, Professor W. W. WATTS, *and* Mr. G. W. WILLIAMS.

On some Excavations in the Cambrian Rocks of Comley, Shropshire, 1907. *By* E. S. COBBOLD, *F.G.S.*

THE locality of Comley has long been classical in geology as the only place in Shropshire where Lower, Middle, and (so-called) Upper Cambrian rocks, occurring in juxtaposition, are all known to yield fossils.

The chief point of interest has been the little Quarry of Comley, in which both the characteristic genera of Trilobites of the Lower and Middle divisions of the Cambrian system—namely, *Olenellus* and *Paradoxides*—occur in close association.

These rocks of the Comley district were first claimed as Cambrian by Dr. Chas Callaway [1] in 1878, and paralleled by him with the Hollybush sandstone of the Malvern district.

In 1888 Professor Lapworth announced [2] the discovery of an *Olenellus* (*O. Callavei*, Lapw.) from the band of purplish-red calcareous sandstone of the Comley Quarry, which band has become generally known among English geologists as the Olenellus Limestone band of Comley, or, locally, the Olenellus Limestone.

In 1891 Lapworth described and figured the *Olenellus*,[3] and at the same time announced his discovery of a *Paradoxides* (which he named *P. Groomii*) from the conglomerates and limestones overlying the Olenellus Limestone in the same quarry.

Although it was thus well known that both Lower and Middle Cambrian rocks were present in the locality, the line between them had not hitherto been exactly determined.

The Cambrian formations of the Comley area hitherto recognised are as follows :—

III. *Upper Cambrian Shales*, so called (the Shineton Shales of Callaway, *op. cit.*).

II. *The Comley Sandstone* of Lapworth, *op. cit.*, divisible into a lower and an upper portion, the latter representing parts of the Middle Cambrian, and the former parts of the Lower Cambrian of other regions.

I. *The Wrekin Quartzite* of Callaway at the base.

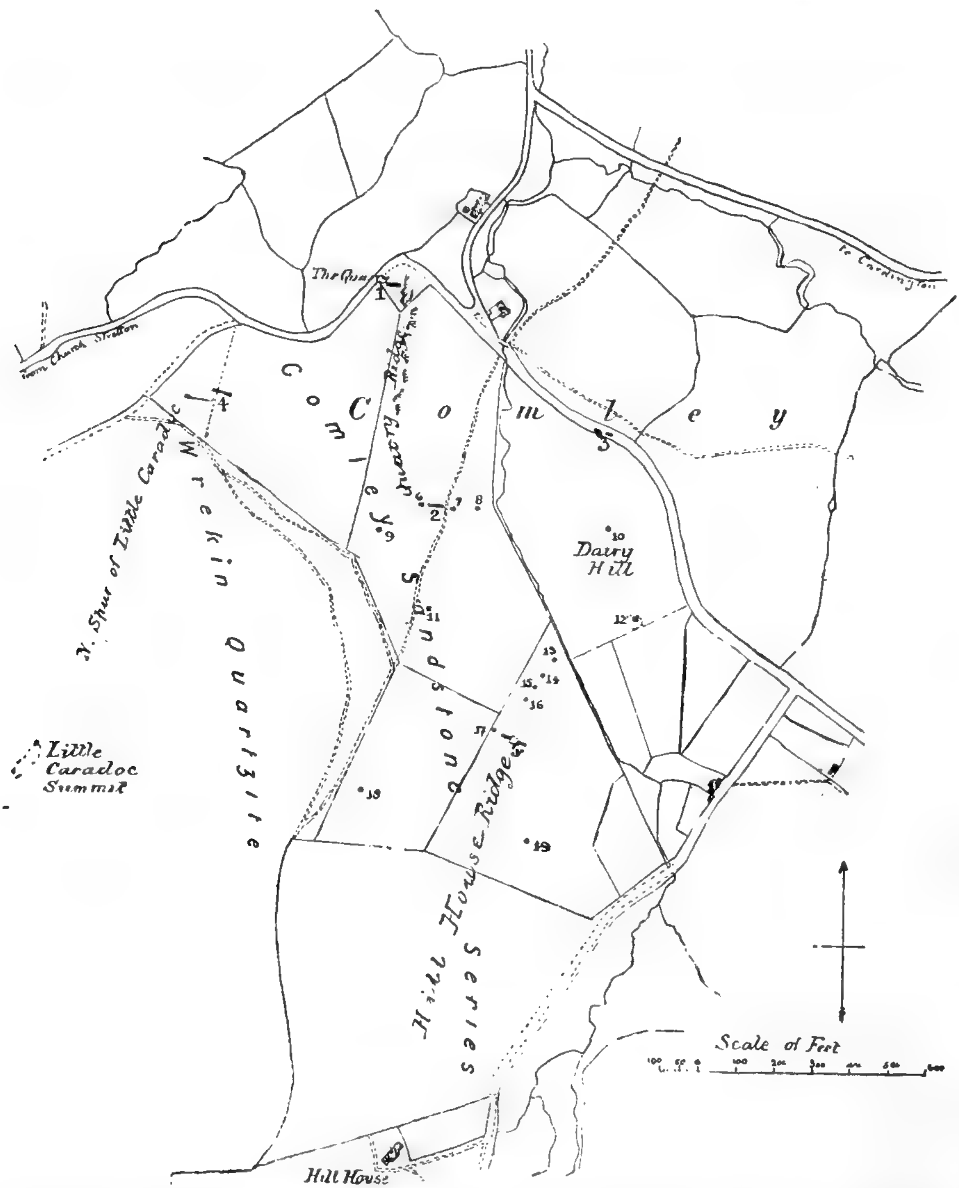
The excavations described in this report have been confined to the Comley Sandstone Series above mentioned.

The geology of the Comley area presents considerable difficulties owing to the obscure and faulted nature of the ground. It will be seen from the accompanying sketch-map that the main mass of the area under description is occupied by the Comley Sandstone Series. This is underlain to the west by the Wrekin Quartzite, but the only fairly

[1] Callaway, *Quart. Jour. Geol. Soc.*, vol. xxxiv. 1878, p. 759.
[2] Lapworth, *Geol. Mag.*, December 3, vol. v. 1888, p. 484.
[3] *Ibid.*, vol. viii. 1891, p. 529.

consecutive section hitherto known has been a thickness of about 30 feet of Comley Sandstone exposed in the Quarry itself, which has been worked at frequent intervals for more than thirty years for the extraction of road stone.

There are, however, many patches of Lower and Middle Cambrian rocks to be seen in the Comley area, but they are isolated, and the



stratigraphical relationships and lithological details of such beds as have hitherto yielded fossils have necessarily remained undetermined for want of sufficient evidence.

Professor Lapworth has mapped the area, and has freely shown his maps to myself and others, but the results of his investigations are as yet unpublished.

Fairly large collections of fossils have been made from Comley, but many of the species appear to be new to Britain or are as yet undescribed. It is impossible, therefore, to give complete lists.

Dr. Callaway quotes [1] from the Quarry 'a minute roundish *Lingula*, *Kutorgina cingulata*, Bill., and *Serpulites fistula*, Holl.'

Professor Lapworth quotes [2] as associated with his *Olenellus Callavei* in the Olenellus Limestone '*Kutorgina cingulata*, Bill., *Linnarsonia sagittalis*, Walcott, *Hyolithellus*, cf. *H. micans*, Walcott, and *Elliptocephalus* sp.'; and from the beds yielding his *Paradoxides Groomii* 'forms of *Ptychoparia*, *Obolella*, and *Protospongia*.'

In 1892 Mr. Rhodes collected largely in the area for H.M. Geological Survey under the direction of Professor Lapworth, and his specimens are still under examination. Numerous other geologists, including myself, have collected fossils from the Quarry and neighbourhood, obtaining them to a large extent from loose blocks of material, and it is often difficult, or even impossible, to assign the specimens to their respective lithological horizons.

Being desirous of establishing the exact horizon of some specimens of *Microdiscus lobatus*, Hall, which I had collected from a spot that was pointed out to me by Mr. Rhodes in 1892, situated in the fields about 200 yards south of the Quarry, which species was being described, among others, by Mr. Philip Lake in his Monograph on the Cambrian Trilobites,[3] I commenced an excavation, in June 1907, at the spot in question, and exposed a series of grey limestones (which had not hitherto been recognised in the Quarry) lying just above, and conformably with the Olenellus Limestone.

Professor Lapworth, being interested, kindly contributed to the preliminary expenses, and considered it most desirable to extend the excavations, if possible, to several other critical spots in the area. Subsequently, on the appointment of the Geological Excavation Committee, Section C, at the Leicester meeting of the British Association, a grant was awarded by the Committee for the purpose of carrying out these excavations, and the present report summarises the results of this work down to the present time (June 1908).

Description of the Excavations.

The positions of the excavations already carried out are shown on the accompanying sketch map. They are of two kinds :—

(*a*) Transverse excavations, numbered 1 to 5 on the map, and indicated by short thickened lines. These are trenches for the purpose of ascertaining the sequence of the strata above or below known exposures of rock. They are cut through the soil and subsoil (where the depth is not excessive) to solid rock, and allow of the observation of the lithological characters of the various layers, and in some cases of the collection of fossils.

(*b*) Vertical excavations or trial holes, numbered 6 to 19 on map, put down to ascertain the nature of any solid rock existing between

[1] *Op. jam cit.*

[2] *Op. jam cit.*, p. 532; also 'The Geology of S. Shropshire,' Lapworth and Watts, *Proc. Geol. Assoc.*, London, 1894, p. 310.

[3] *Pal. Soc.*, vol. lxi. 1907, 'Cambrian Trilobites,' p. 32.

known natural exposures and the feasibility or otherwise of opening up additional transverse sections.

Note.—The letters distinguishing the various beds on the following pages are only applicable in each case to the individual sections under description, and are not to be taken as implying correlation of strata. The names employed are either existing appellations for strata or groups of strata in use among geologists, or new names now proposed for adoption. The latter, where used for the first time, are given with quotation marks. The beds are in all cases described in descending order.

No. 1. The Comley Quarry Section.

The rocks described in Part I. are those of the eastern portion of the Quarry enclosure, and have long been exposed by the ordinary quarrying operations carried out for the extraction of road metal.

The rocks described in Part II. are those of the western portion of the Quarry enclosure as laid bare for the first time by the present excavations and by the clearing away of débris and overgrowth from an old disused quarry face.

All the strata have an approximately N. and S. strike, with an easterly dip of about 70°.

Owing to the working back of the Quarry face and some faulting the section now to be seen is not quite the same as it was formerly.

PART I. *Rocks previously exposed by the ordinary Quarrying Operations.*

East End of Section:—

a. The Comley '*Quarry Ridge Grits*,' with *Paradoxides*.

	Ft.	In.
a_1 Brownish, coarse, quartzose *Grits* with much glauconite and, in places, becoming conglomeratic. Bedding planes, ill-defined, at 2 to 3 feet intervals (top not seen)	21	0
a_2 *Conglomeratic* bed, becoming calcareous at the base, with a matrix quite similar to that of the grits above (a_1), but containing (i) pebbles, (ii) rather large subangular to angular blocks of rocks derived from the beds below, and (iii) very many black or brown lumps of phosphatic material	3	0

The included materials comprise:—

(i) pebbles, more or less rounded, of quartz and of igneous rocks, one of which compares very closely with the 'granitoidite' of the Cardington Hill volcanic group.

(ii) lenticular pieces of limestone, some of which exactly correspond with the 'French Grey Limstone' bed *d* below, and have, in the quarry, or in Section No. 2 (see page 236), or in intervening natural exposures, yielded many fragments of *Olenellus* referred to *O.* (*Holmia*) *Callavei*, Lapw.; *Anomocare* (*Agraulos* in the sense used by Walcott), a pustulate species not yet identified; *Linnarsonia* and other Brachiopods; and subangular to angular pieces of greenish and yellowish micaceous sandstone very similar to beds *f* below.

(iii) black or brown lumps of phosphatic material, which are very irregular in shape, often weathered out so as to form cavities; they may be contemporaneous with the formation of the bed.

Where very calcareous the matrix of the conglomerate is of a pinkish grey colour very similar to that of the 'French Grey Lime-

	Ft.	In.
stone' bed *d* below, but usually showing an admixture of glauconite grains and earthy matter not found in that bed. It is from the grey portions of the bed that I have collected fragments of a large *Paradoxides* referable, with doubt, to *P. Groomii*, Lapw.		
b. The *Black Limestone* (Callaway and Lapworth):—		
A very dark rock with rounded quartz grains, much glauconite, and abundant black lumps of phosphatic material. This bed is sometimes found soldered to the overlying conglomerate (a_2), especially in the deeper parts of the Quarry. Near the surface it is, or was (for it is nearly all quarried away at the higher levels), separated from it by clayey matter. Maximum thickness	0	9
Hyolithus fistula (?), *Salterella* (perhaps 2 species) and Brachiopods.		
c.[1] *Grey Limestone* and *Fault rock*	0	9
d. The '*French Grey Limestone*':—		
A pinkish grey compact limestone becoming purple or red in places and crowded with fossil fragments, which are shown upon the yellowish weathered surfaces, without glauconite or phosphatic inclusions	1	0
Aristozoe, cf. *A. rotundata*, Walcott, and Brachiopods.		
. . . .		
e. The *Olenellus Limestone*:—		
A red and green deposit, sandy as a rule and almost shaley in the upper part, but becoming very calcareous in certain layers, from the presence of nodules of compact sandy limestone the weathered surfaces of which exhibit abundant fragments of *Olenellus* . . . . about	2	6
The fossils detected include *Olenellus* (*Holmia*) *Callavei*, Lapw.; *Anomocare* sp.; *Agraulos*, possibly two species; *Microdiscus* sp., cf. *M. Helena*, Walcott; *Hyolithus* sp., probably *nov.*; *H. socialis*, Linnrs., *Linnarsonia* and other Brachiopods.		
f. The '*Lower Comley Sandstone*':—		
f_1 Soft red and green micaceous sandstone, with sandy shales in thin layers	4	0
PART II.—*Rocks exposed by the new excavation.*		
f_2 Green and rusty micaceous sandstones, being the downward continuation of f_1, in beds 1 to 3 feet thick, with at least three separate layers (situated at 7, 11, and 14 feet below the base of the Olenellus Limestone), exhibiting rusty spots weathering out into cavities	27	0
f_3 Green micaceous sandstone rather softer in texture than e_2, weathering brown, in thin beds 1 to 2 inches thick (base not seen	20	0
Total thickness observed . . .	80	0

West End of Section.

NOTE.—Similar sandstones to the above (f) are traceable at intervals along the roadside for a distance of twenty yards south-westerly from the end of the excavation, indicating (if there is no repetition and the dip remains constant) a further downward thickness of the sandstone on the E. and W. line of section of about 40 feet.

[1] The rock marked *c* probably represents some portions of the '*Grey Limestones* of Section No. 2, p. 6, but is a good deal crushed by strike faulting.

No. 2.—Excavation and Section in fields 200 *yards south of the Comley Quarry.*

At this spot there was an old cutting overgrown with grass in a little knoll near the southern termination of the Quarry Ridge (see map). It showed protruding bosses of grit and conglomerate similar to those seen in the Quarry, together with loose angular pieces of grey or purplish limestone.

I had one side of this cutting cleared of soil, and prolonged the section thus obtained in both directions by a new trenching excavation. The beds have a strike approximately north and south, and dip to the east at an angle of about 65°.

The old cutting and the new trenches are not quite at right angles to the strike, but allowance for this has been made in taking the measurements.

East End of Section.

	Ft.	In.
a. The *Quarry Ridge Shales* :—		
Comminuted pale greenish grey shale, including (in the lower part of its section) a band of hard glauconitic grit 3 inches thick, striking parallel with the beds below. The base of this shale group not seen owing to the presence of a fault running nearly parallel with the strike and hading easterly. The thickness of this group may be as much as 200 or 300 feet .	10	0
b. The *Quarry Ridge Grits* :—		
b_1 Grit broken into angular fragments, say	5	0
b_2 Well-bedded grit	5	0
b_3 Conglomeratic grit with black flaggy material about the middle and at the base	12	0
These grits and conglomerates agree precisely with those of the Quarry (a_1, a_2, Section No. 1).		
c. The *Black Limestone* :—		
The upper half of this shows a dark grey sandy matrix with many black phosphatic lumps; the lower half has less of the phosphatic material	1	0
Hyolithus fistula, Holl. (?).		
d. The '*Grey Limestones*' :—		
A series of fossiliferous limestones varying in colour from a reddish purple through greenish grey to pale grey.		
d_1 A pale grey limestone very full of fossil fragments	0	3
Fossils:—*Protolenus* sp.; *Microdiscus lobatus*, Hall; *M.* sp.$_1$ of medium size and having a punctate test.; *M.* sp.$_2$ somewhat intermediate between the two; *Hyolithus*, cf. *H. corneolus*, Holm.; *H. fistula*, Holl. (?), and Brachiopods.		
d_2 A reddish purple limestone becoming pale grey in places . . .	0	6
Fossils are very plentiful:—*Microdiscus lobatus*, Hall; *M. speciosus*, Ford; *Anomocare* (*Agraulos* of Mathew and Walcott), cf. *A. strenuus*, var. *nasutus*, Walcott; *A.* sp.$_1$, with glabella furrows transverse; *A.* sp.$_2$, with glabella furrows directed backwards; *A.* sp.$_3$, a smaller form, with front margin reflexed and glabella almost keeled; *Hyolithus fistula*, Holl. (?); *H.* sp., cf. *H. lenticularis*, Holm.; *H.* sp.; *Helenia* (?) sp. nov. and Brachiopods.		

	Ft.	In.
d_3 A dark grey limestone with many phosphatic lumps, some glauconite, and having purple and green patches of colour .	1	0
[Fossils more fragmentary, not yet separately collected.]		
d_4 A greenish grey rock with plentiful black phosphatic lumps .	0	9
[Fossils fragmentary, not yet separately collected.]		
e. The *French Grey Limestone* :—		
A pale pinkish grey limestone in two bands, each about 3 inches thick, with a few pieces of dark phosphatic material . .	0	6
There are some patches of this limestone which have a granular or sandy aspect, and the colour is then greenish.		
Anomocare vel Agraulos sp., a very pustulate form; fragments of *Olenellus* sp. and Brachiopods.		
f. The *Olenellus Limestone* :—		
Immediately below the French grey limestone the cutting showed some red sandy clay, and embedded in this material there protruded from the bottom of the excavation some nodules of red sandy limestone characteristic of the Olenellus Limestone, as seen in the Comley Quarry, and yielding fragments of *Olenellus* and *Microdiscus* sp.		
Total thickness of red material	2	6
g. The *Lower Comley Sandstone* :—		
g_1 Greenish soft sandstone or sandy shale, cf. bed f_1, Section No. 1 (base not seen)	0	6
	39	0

Some 12 feet beyond the end of the trench a trial hole (No. 6 on map) was excavated disclosing—

g_2 Green sandstone, cf. beds f_2, Section No. 1.

West End of the Section.

NOTE.—About 30 feet east from the eastern end of the Trench a trial-hole (No. 7 on map) was sunk at the site of an old saw-pit, disclosing comminuted pale grey shale exactly like that of bed *a*, Section 2, above.

At a further distance of about 60 feet in the same direction another trial-hole (No. 8 on map) was sunk near the Comley Brook. This disclosed clayey material similar to that found above the shale in Trial-hole No. 7, but having in it some angular pieces of brownish green, flaggy, glauconitic grit, with small quartz pebbles. No dip or strike could be determined here.

Excavation No. 3.—North End of Dairy Hill, about 200 yards south-east of the Comley Quarry.

I made this excavation for the purpose of ascertaining the structure of Dairy Hill. Professor Lapworth had mapped it as a dome, and had found fragments both of the Olenellus Limestone and of the Quarry Ridge grits in the surface of an old lane, which curves round the north end of Dairy Hill (see map), but it was uncertain if they were *in situ*. Holes were made in the south bank of the lane, which is here about 8 feet high, and disclosed plentiful nodules of the Olenellus Limestone and of a green standstone referable to the Lower Comley Sandstone (beds *f* of the Quarry) beneath it. The Quarry Ridge grit (the conglomeratic portion) is traceable along the road surface in a curved line more or less parallel to the contour of Dairy Hill, and the whole of the beds dip north.

It is obvious that the lane has at this point cut well into the northern end of a dome of the Quarry Ridge grits and has just reached the Olenellus Limestone and the Lower Comley Sandstone below it. I found no traces of any of the French Grey, Grey, or Black Limestones in this excavation; further excavations are necessary before their apparent absence can be accounted for.

The Olenellus Limestone in the bed and bank of the road yielded fragments of *Olenellus* having characteristics of *O.* (*Holmia*) *Callavei*, Lapw., and *Linnarsonia*.

Excavation No. 4.—North Spur of Little Caradoc, 200 yards west-south-west of the Comley Quarry.

The object of this excavation was to open up a section of the lowest beds of the Lower Comley Sandstone and to ascertain the character of their junction with the underlying Wrekin Quartzite below. The Quartzite is known to wrap round the eastern side of Little Caradoc Hill, and there are traces of it in this northern spur. There are also at this point some natural exposures of greenish micaceous sandstone, not unlike the Comley Sandstone of the Quarry, and of a coarse-grained dolerite which, higher up the hill, intervenes between the Quartzite and the core of Pre-Cambrian rocks.

Two trenches were opened in a piece of uncultivated ground west of the Comley Quarry, and separated from it by nearly 200 yards of cultivated land showing no exposure of solid rock.

One of these trenches was continued east, as far as circumstances allowed, into the arable field; the other was carried west, to find the Quartzite and fix its point of contact with the dolerite.

Some of the beds in the first trench could be exactly matched in the second, and the sections displayed in both are given below as one continuous whole.

The beds dip west, but as they are, in all probability, inverted, the section is described from east to west, as representing the descending order of the beds.

a. Lower Comley Sandstone.

	Ft.	In.
a_1 Fine-grained greenish micaceous sandstones in compact, or flaggy, or rubbly beds, dipping about 50° westwards, and varying a good deal in hardness . . . . . About	30	0
Yielding *Hyolithus* sp. near *H. tenuistriata*, Linn.		
a_2 Fine grit with well-rounded grains, 2 inches.		
Sandy clay, 4 inches.		
Very dark coarse grit with some dark green grains (?) glauconite, 2 inches.		
Bluish-grey calcareous grit weathering to a dark incoherent sand-rock, 12 inches.		
Grey clayey shale, 6 inches.		
Rib of hard fine-grained micaceous sandstone, 18 inches.		
Sandy clay, 12 inches . . . . . Total thickness of a_2	5	0
a_3 Fine-grained greenish flaggy micaceous sandstones	15	0
a_4 Hard greenish micaceous sandstones in more compact beds dipping westerly at about 50°	12	0
a_5 Much harder brownish micaceous sandstone having a more quartzite-like aspect	4	0
Total thickness of sandstones seen	66	0

Interval of about 20 feet, in which no rock showed at the bottom of the trench.

b. The '*Wrekin Quartzite.*'

	Ft.	In.
b_1 Broken angular fragments of fine-grained Quartzite, much brecciated, the cracks only partially filled . . . . about	4	0
b_2 Bottom of trench showing no bedded rock but much clayey material with fragments of Quartzite flags 1 to 2 inches thick, representing a thickness of . . . . . . about	10	0
b_3 Coarse granular Quartzite, much broken and weathered in places to a dark incoherent grit . . . . about	4	0
b_4 Well-bedded coarse-grained Quartzite, dipping west at about 85°, underlain by a clay-parting	1	0
b_5 Compact glistening fine-grained Quartzite and clay-parting . .	0	6
b_6 Compact glistening fine-grained Quartzite and clay-parting . .	0	6
b_7 Coarse-grained white Quartzite, weathering in places to a dark incoherent quartz grit	2	6
Total thickness of Quartzite seen	22	6

Possible Fault:—

c. Dolerite, weathered or sheared into small lenticles $\frac{1}{4}$ to $\frac{1}{2}$ inch thick and much decomposed, becoming rather more compact at a distance of 2 feet from the Quartzite.

This Section is of interest as showing:—

A. The general nature of the higher beds of the Wrekin Quartzite with their varying thicknesses and clayey partings;
B. A continuous section of about 66 feet of the Lower Comley Sandstone, with the occurrence in it of a *Hyolithus* and some calcareous gritty bands and shales;
C. A certain amount of graduation from beds with a thoroughly quartzite facies to those of the sandstone facies.

It is uncertain whether the 20 feet interval between the two formations represents a fault or not. The subsoil at this point is a very loose sandy gravel (probably glacial), and it was considered unsafe to deepen the narrow trench sufficiently to find solid rock.

Excavation No. 5.—Hill House Ridge, North End.

At the northern extremity of Hill House Ridge (see map) a small quarry was opened some ten or fifteen years ago for the purpose of extracting stone for rough walling from two strong beds of grey grit, beneath which lies a band of dark brown incoherent grit. In this dark grit I had previously found some casts of fragments of trilobites.

In order to endeavour if possible to fix the position of these grits in the general Comley Series, I had trenches cut crossing the strike of the beds to east and west of the little quarry.

The section thus exposed divides itself into three parts: (1) The trench east of the quarry; (2) The quarry itself; and (3) The trench west of the quarry.

East End of the Section:—

PART I.—*Trench East of the Little Quarry.*

a. '*Hill House Shales*':—

	Ft.	In.
a_1 Sandy shale much disturbed; dip and thickness unknown . .	5	0
Probable Fault:—		
b. '*Hill House Grits*':—		
b_1 Rough, brown, glauconitic grits, flaggy in places and occasionally almost conglomeratic from the presence of inclusions of shaley material; dip 55° East . . . . . . about	12	6
Ptychoparia (?) sp., and many fragments of Trilobites.		

PART II.—*The Hill House Ridge Quarry itself.*

	Ft.	In.
b_2 Quartzose grits, almost white, and with little glauconite; dip about 45° East	7	0
b_3 Dark-brown incoherent grit with trilobite fragments . . .	0	6
b_4 Brown quartzose glauconite grit	5	0

PART III.—*Trench West of the Quarry.*

	Ft.	In.
b_5 Soft dark conglomeratic grit with phosphatic lumps	3	0
b_6 Greenish quartzose grit	3	0
b_7 Black flaggy grit	0	6
b_8 Dark grits, incoherent in places	6	6
	43	0
c. '*Hill House Flags*':—		
c_1 Black flaggy grit; dip about 30° to the East	0	4
c_2 Dark sandy and calcareous material with much phosphate . .	1	6
Dorypyge sp.		
Paradoxides (?); *Hyolithus fistula* (?), Holl., and Brachiopods		
c_3 Black calcareous flaggy grits, 1 inch and 3 inches thick; dip about 10° to the east. Base not seen	2	0
Total thickness seen in section about . .	47	0

West End of the Section.

So far as surface features show, the deposit lying next below these Hill House Flags appears to be the upward extension of the Quarry Ridge Shales seen in Excavation No. 2, but there is every probability that the junction is a faulted one, and that the sequence is not complete. A trial-hole (No. 17) put down 12 yards west of the end of the section near the fence failed to reach solid rock.

Trial-holes Nos. 14, 15, 16 on map (see below, p 241) are in strata which appear to belong to the Hill House Shales, and indicate a considerable thickness of these beds.

Vertical Excavations or Trial Holes.

Nos. 8, 9, 11, 17, 18, 19 disclosed no solid rock.

No. 10, at the top of Dairy Hill, showed broken grits referable, with doubt, to the Quarry Ridge Grits, with indications of nearly horizontal bedding.

No. 12 consisted of clearing away some of the débris in an old quarry near the south fence of the Dairy Hill field in order to ascertain the dip of the beds.

It showed the following vertical section of beds lying nearly horizontally :—

	Ft.	In.
a. A coarse somewhat conglomeratic bed of grit or sandstone with rusty coloured blotches and greenish earthy patches . . .	0	5
b. Micaceous green flaggy sandstone	0	4
c. ,, ,, but more compact and rather coarser	0	9
d. Micaceous sandstone with rusty spots ; cf. beds *f* of Excavation No. 1. Base not seen	2	0

The general aspect of these beds recalls those found below the Olenellus Limestone of the Comley Quarry.

Nos. 13, 14, 15, 16, were sunk on the northern slopes of Hill House Ridge to ascertain the nature of the shales there apparently overlying the Hill House Grits, and to localise the exact position of a fault mapped by Professor Lapworth.

No. 13, near the Comley Brook, exhibits beds of grit and shale dipping to the south-west at about 45°.

Nos. 14, 15, 16, showed shales often gritty and micaceous with included bands of harder shale and grit, all with a nearly vertical dip and a north and south strike.

It is clear that the fault in question lies between Nos. 13 and 14.

Results.

Previous to the time when these excavations were commenced it was well known to geologists that in the Comley area the Wrekin Quartzite underlay the Comley Sandstone Series ; that in this Sandstone series occurred a fossiliferous group of strata of no great vertical thickness, which was partly exposed in the Comley Quarry ; and also that the lower beds of this Quarry group yielded the *Olenellus* fauna and its higher beds, *Paradoxides* ; but the precise line of stratigraphical demarcation between the two sets of strata yielding the older fauna and those yielding the younger fauna, even within this little fossiliferous group, remained undetermined. And, although it was known that both above and below the beds exposed in the quarry there occurred a comparatively great thickness of strata belonging to the local Comley Sandstone Series, that series remained undivided owing to the paucity of natural sections.

The results of these excavations enable us for the first time to fix almost exactly the local stratigraphical line of division between the Lower and Upper Comley Series, and to give details as to the sequence and characteristics of the various lithological bands in the fossil-bearing group for some distance above and below that line, and thus permit of the fixation of the true stratigraphical horizons of the fossils which have been at various times collected from these beds, or from loose fragments derived from them.

Again, although it cannot be claimed that these excavations have furnished a sufficiency of evidence to enable geologists to distinguish all the local members of the Comley Sandstone Series, they have supplied a large amount of additional testimony in support of the view that not only is the series as a whole separable into two main divisions—an upper and a lower series distinguishable by their fossils—but that each of the two divisions will in time prove capable of subdivision into recognisable stratigraphical sub-groups.

As matters now stand it would appear that the components of the Comley Series, as developed in this little area, may be somewhat as follows:—

1. THE LOWER COMLEY SERIES, whose lowest beds graduate upwards from the Wrekin Quartzite below, through an unknown thickness of *Lower Comley Sandstone*, into the fossiliferous *Olenellus* group at the top (some 5 or 6 feet in total thickness, and composed in ascending order of (1) *the Olenellus Limestone, the French Grey Limestone*, and the *Grey Limestones*). The affinities of the Black Limestone have yet to be determined.

2. THE UPPER COMLEY SERIES.—The lowest group of this consists of the *Quarry Ridge Grits* (some 24 feet in thickness), made up of a lower *conglomeratic Zone* with the *Paradoxides* fauna and a higher gritty zone with few fossils. These Quarry Ridge Grits are apparently succeeded by a thick band of shales, *the Quarry Ridge Shales.* Still higher in the succession comes the *Hill House Group*, made up of the *Hill House Flags* below, the *Hill House Grits* in the middle, and the *Hill House Shales* above.

While the original object with which these excavations were commenced—*i.e.*, the fixation of the relative systematic positions of the lithological zones which have already yielded fossils in the Comley Quarry and its immediate neighbourhood—has been attained, nevertheless the stratigraphical succession of the component lithological zones of the Comley Series as a whole is as yet far from being established; and, bearing in mind the fact that in this Comley area the Cambrian strata of Shropshire are known to be far more fossiliferous than elsewhere, it is most desirable that the work shall be continued.

Throughout these investigations I have had repeated help and encouragement from Professor Lapworth, which I gratefully acknowledge.

I am also much indebted to Mr. Philip Lake for help in the determinations of the Trilobites, and to Professor Theodore Groom for a report on the Hyolithidæ, &c.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Professor P. F. KENDALL (*Chairman*), Dr. A. R. DWERRYHOUSE (*Secretary*), Dr. T. G. BONNEY, Mr. F. M. BURTON, Mr. F. W. HARMER, Rev. S. N. HARRISON, Dr. J. HORNE, Mr. J. LOMAS, Professor W. J. SOLLAS, *and* Messrs. J. W. STATHER, R. H. TIDDEMAN, *and* W. T. TUCKER, *appointed to investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.* (*Drawn up by the Secretary.*)

Reported by Professor KENDALL, *M.Sc., F.G.S.*

Robin Hood's Bay.—In the spring of the present year three boulders of Shap granite were exposed in the cliffs near Stoup Beck. Two were large, well-worn blocks, about 2 to 3 feet long; the third not more than 8 inches long. One of the larger still remains *in situ.* It lies in undisturbed boulder clay 20 feet above high-water mark, exactly 100 yards south of Stoup Beck. The long axis is directed about N. 30° W., and the southern end is slightly raised, in which respect it resembles the great majority of the large boulders in the same deposit.

The base of the boulder is about 4 feet below an ill-defined junction, between a dark bluish-brown boulder clay, very heavily charged with stones and traversed by shear planes, often much contorted, and an upper paler dun clay with fewer stones. It may be that the differences of aspect are due to differences in exposure to spray.

The lower clay was examined carefully to discover with what grouping of erratics the Shap granite boulders were associated, and every stone of obviously foreign derivation was scrutinised especially with the object of ascertaining whether the porphyrites of the Cheviot type and Greywacke sandstones, such as occur in the Tweed Valley above Melrose, were present in such numbers as to identify the boulder clay with the beds forming the highest members of the Glacial Series in many parts of the coast tract of Yorkshire.

Porphyrites formed the predominant element of the foreign stones, but they were mainly of a very dark-purple tint; while the red porphyrites that preponderate in the Cheviots were represented by few examples. The Greywacke sandstone, including a perfectly angular slab 2 feet in length, did not resemble any type that I have seen in the Tweed Valley.

Decomposed melaphyres with amygdaloids were common; basalts and dolerites less so. Two pebbles of trachyte were found and one pebble of rhomb porphyry. Three flints (not of Yorkshire type), one small pebble of granite, a granophyre (possibly Buttermere), one piece each of Brockram and Old Red sandstone, some Carboniferous limestone, and Magnesian limestone completed the series of certainly foreign stones.

Of local, or possibly local, rocks the following were observed :—

Sandstones from the Estuarine Series (these constituted nearly the whole of the large blocks and many of the smaller stones).

Equisetum stem.
Harpoceras bifrons.
Jet (abundant).
Middle Lias ironstone.
Lower Lias shale and limestone.
Gryphæa incurva.
Oxynoticeras oxynotum.
Gypsum (a lump as large as a cricket-ball).

Reported by Mr. Thomas Sheppard, *F.G.S.*

From Withernsea.—A boulder of black flint containing a specimen of *Belemnites lanceolatus.*

Black flints of this type have long been known in the glacial beds of the Yorkshire coast, and *B. lanceolatus* has been collected in large numbers; but this observation shows them to have a common origin.

As neither the black flints nor *B. lanceolatus* is known in the British chalk, it is concluded that these have probably been derived from an outcrop beneath or beyond the North Sea.

From Dimlington.—A rounded boulder of quartz-rhomb-porphyry,[1] a rock only once previously recorded, viz. from Burstwick.

[1] See Harker, *Proc. Yorks Geol. Soc.*, vol. xiii. pt. ii. pp. 279, 281.

Reported by Mr. J. W. Stather, *F.G.S.*

At Aldborough in Holderness (observed by Mr. Charles Thompson, B.Sc.) a mass of Speeton clay, 12 feet × 7 feet × 1 foot 6 inches, embedded in the boulder clay of the beach. The bedding is still intact, and the contained fossils uncrushed.

The full extent of the boulder could not be seen, as it dipped towards the cliff.

The following fossils were noted :—

Exogyra sinuata.

Belemnites subquadratus.

Astarte senecta.

Also numerous ammonites, all belonging to the zone D_4.[1]

The only other recorded case of a transported mass of Speeton clay is at Flamborough Head, immediately below the lighthouse, though Speeton fossils are very common in the drifts of this coast.

The distance from Speeton to Aldborough is between 20 and 25 miles.

Reported by Mr. H. Culpin.

From a cutting on the South Yorkshire Joint Railway at Stainton Woodhouse, two miles west of Tickhill.

Carboniferous limestone, 6 inches × 5 inches × 4 inches, together with smaller pebbles of the same rock and of grit.

Also a boulder of a dark grey rhyolite with large masses of iron pyrites, probably from the Borrowdale Series.

Reported by Mr. J. Wilfrid Jackson.

A large boulder of Shap granite from Troughbarrow Quarry, near Silverdale, Lancashire.

Reported by Mr. F. W. Harmer, *F.G.S.*

A number of small chips collected by Mr. Harmer from boulders found in the Norwich brick-earth were forwarded by Mr. Harmer. Of these thin sections have been prepared, and have been examined petrologically by the Secretary.

They include a number of holocrystalline acid rocks, including both biotite and muscovite-biotite granites, which it has been impossible to identify up to the present.

Dolerites are represented by two types : one of these (five specimens) is without olivine, and has been identified with the Whin Sill. The other type is olivine-bearing, and has not as yet been identified.

The collection also included Carboniferous limestone, with foraminifera and other small fossils, two pebbles of porphyrite of the Cheviot type, and a quartz hornblende schist, probably Scandinavian.

From the Cromer Clay.—Here, again, was found a number of granites not as yet identified.

Whin Sill was represented by eight specimens.

Olivine dolerites, similar to those from the Norwich brick-earth, also occurred here.

A porphyrite of Cheviot type was also found.

Several quartz-hornblende-schists, bearing a strong resemblance to

[1] Lamplugh, 'On Speeton Clay,' *Q.J.G.S.*, xlv. 575–616.

that from the Norwich brick-earth, occurred, together with a coarse granite with zircon, and a much decomposed elæolite syenite, all probably Scandinavian.

A fine-grained basalt, identical with one from the Norwich brick-earth.

It is hoped that it may be possible to identify the remainder of these rocks and to give a fuller report on the boulder contents of the East Anglian drifts in the next report.

Photographs of Geological Interest.—Sixteenth Report of the Committee, consisting of Professor J. GEIKIE (*Chairman*), Professor W. W. WATTS (*Secretary*), Dr. T. ANDERSON, Mr. G. BINGLEY, Dr. T. G. BONNEY, Mr. H. COATES, Mr. C. V. CROOK, Professor E. J. GARWOOD, Messrs. W. GRAY, W. J. HARRISON, R. KIDSTON, *and* A. S. REID, Professor S. H. REYNOLDS, Dr. J. J. H. TEALL, *and* Messrs. R. WELCH, W. WHITAKER, *and* H. B. WOODWARD. (*Drawn up by the Secretary.*)

SINCE the issue of the last Report in 1904 about 600 photographs have been received for the national collection. Of these 503 have been registered, bringing the total number in the collection to 4,817, and the yearly average to 253.

The annexed geographical scheme gives the distribution of these photographs among the counties. Two English, one Welsh, seven Scottish, and eleven Irish counties are still unrepresented. Somerset, Kent, Yorkshire, and Bute head the list for the year, and the number from the counties of Lincoln, Brecknock, Merioneth, and Fife receive large proportionate increments.

Several of the groups are of exceptional interest. Professor Reynolds sends some excellent studies of rock-structures, due to earth-movement, from Devonshire, some very clear examples of unconformity from Gloucestershire, and a large series of views from Somerset. The same contributor gives a beautiful group of photographs showing the weathering of igneous rocks from the outposts of Cader Idris, and a number of volcanic studies from Arran.

Mr. Bingley contributes many photographs of the Triassic footprints from Storeton Quarry, in Cheshire; a considerable group, mainly illustrating glacial phenomena, from Lincolnshire; and a series of inland and coastal views in Yorkshire. He also sends several interesting views taken in Derbyshire and Durham.

Special mention should be made of a particularly important and most carefully taken set of prints illustrating the 'nailbournes' of Elham and Petham in Kent. In both sets corresponding pairs of views were taken from the same point, one to illustrate the bournes in the flow of the winter 1903–4, and the other the dry state after cessation of this flow in the following summer. These valuable sets, taken by Mr. Buckingham, show how very important the registration of transitory phenomena by photography can be, as in no other way is it possible to secure such a satisfactory and telling record of these remarkable springs. Mankind is so forgetful of them that in some cases houses, roads, and other works are constructed in the path of the intermittent flows. Mr. Buckingham has also collected a series of important facts relating to former flows of these bournes, as well as to the flows of 1903–4.

Counties	Previous Collection	Additions (1908)	Total
ENGLAND—			
Cheshire	69	12	81
Cornwall	67	21	88
Derbyshire	45	20	65
Devonshire	180	26	206
Durham	136	9	145
Gloucestershire	67	17	84
Hampshire	47	4	51
Herefordshire	1	1	2
Kent	112	43	155
Lancashire	77	3	80
Leicestershire	148	15	163
Lincolnshire	6	27	33
Norfolk	110	9	119
Northamptonshire	18	1	19
Northumberland	73	5	78
Shropshire	55	8	63
Somersetshire	78	44	122
Staffordshire	53	1	54
Suffolk	45	2	47
Surrey	58	11	69
Sussex	12	6	18
Westmorland	82	5	87
Yorkshire	847	41	888
Others	337	—	337
Total	2723	331	3054
WALES—			
Brecknock	8	29	37
Carnarvonshire	106	3	109
Merionethshire	19	33	52
Montgomeryshire	11	2	13
Radnorshire	20	1	21
Others	127	—	127
Total	291	68	359
CHANNEL ISLANDS	38	—	38
ISLE OF MAN	61	—	61
SCOTLAND—			
Argyllshire	23	9	32
Bute	6	40	46
Fifeshire	43	21	64
Inverness-shire	138	9	147
Others	249	—	249
Total	459	79	538

Counties	Previous Collection	Additions (1908)	Total
IRELAND—			
Antrim	278	9	287
Clare	13	2	15
Cork	21	2	23
Donegal	50	4	54
Dublin	42	2	44
Galway	29	4	33
Others	213	—	213
Total	646	23	669
ROCK STRUCTURES, &c.	96	2	98
Summary.			
ENGLAND	2723	331	3054
WALES	291	68	359
CHANNEL ISLANDS	38	—	38
ISLE OF MAN	61	—	61
SCOTLAND	459	79	538
IRELAND	646	23	669
ROCK STRUCTURES, &c.	96	2	98
Total	4314	503	4817

Mr. Buckingham also contributes a photograph of the cliffs of St. Margaret's Bay before the great rock-fall of January 1905, and several others taken after that fall.

At my request Mr. Hodson, of Loughborough, kindly took a large series of beautiful photographs of the Blackbrook Valley in Charnwood Forest. This valley is of exceptional interest, because it is the unique example in the Forest of a Triassic valley out of which the Triassic material has been almost completely scooped. It therefore differs in landscape character from any other valley in the Forest, and indeed in the eastern part of England; but its special features have now been lost, as it is submerged under the reservoir of the Loughborough waterworks constructed by Mr. Hodson. Unhappily Mr. Hodson died shortly after he had completed this work, and his many contributions to the collection will be much treasured.

A serious loss to the Committee is caused by the death of one of its most active members, Mr. W. Jerome Harrison, who may be styled the pioneer of geological photography and also of systematic photographic survey work. The collection contains some hundreds of specimens of his work, and the Committee still hold a considerable series of photographs in Suffolk, which only need indexing to be incorporated in the collection. It was at the York meeting of the Association that Mr. Harrison brought before the Conference of Delegates an important paper on 'The Desirability of Promoting County Photographic Surveys,' one outcome of which has been the attempt to collect and exhibit a set of scientific photographs each year illustrating the district in which the Association meets. An admirable example of such a collection was exhibited at Dublin during the current meeting.

Mr. J. G. Goodchild, also a member of the Committee since 1893, was removed by death in 1906.

Other contributions include a beautiful set of photographs of granite sills, raised beaches, and other phenomena in Cornwall taken by Messrs. G. V. and H. Preston, who send also some prints taken in Staffa; a series of photographs taken in connexion with the excursion of the British Association along the Cromer coast in 1904 by Mr. G. Hastings; several photographs taken in Surrey by Mr. Baldock and Mr. Robarts; an interesting set of miniature denudation phenomena taken at Bexhill by Dr. Horace Brown; and some important photographs taken in Skye by Mr. R. F. Gwinnell and Mr. J. A. Smythe.

Lastly the Committee would give special mention to the set of photographs, mostly of waterfalls and related phenomena in Brecknock, by Miss F. Neale, described and classified by Mr. F. T. Howard; photographs taken in Ireland by Mr. R. Welch, Mr. Cleland, and Miss Andrews; and a careful selection of his instructive photographs of volcanic and allied phenomena taken by Mr. A. S. Reid in Fifeshire.

To all these gentlemen and ladies the thanks of the Committee are due, and to the list they would also like to add the following for photographs given or help rendered :—Mr. E. A. N. Arber, Professor J. W. Carr, Mr. J. Carver, Mr. E. S. Cobbold, Mr. F. G. Collins, Mr. L. H. Cooke, Mr. A. K. Coomaraswamy, Mr. H. Divers, Mr. C. H. B. Epps, Mr. Friendship, Professor E. J. Garwood, Mr. F. Greenwood, Mr. J. Hopkinson, Mr. J. W. Jackson, Miss M. S. Johnston, Mr. A. T. Metcalfe, Mr. G. W. Moore, Mr. H. Pickles, Mr. R. H. Rastall, Mr. C. Davies Sherborn, Mr. W. E. Smith, Mr. J. A. Smythe, Mr. F. S. Snell, Mr. W. Whitaker, Dr. D. Woolacott, and Mr. A. Young.

A certain demand still exists for the published series, and, as each order yields a small profit, the balance of the Committee stands at 125*l.* 10*s.* 1*d.* after current expenses of mounting and storing have been paid.

It has not been found possible hitherto to proceed with the publication of the contemplated second issue, but it is proposed to begin work upon it at once, and next year's Report will probably record the publication of the first series.

A selection from the first published issue has been exhibited at the Science Section of the Franco-British Exhibition, and has received the award of a Diploma of Honour.

No important additions have been made to the duplicate series. This series has been exhibited by Mr. Whitaker at several scientific societies, including the Tunbridge Wells Natural History Society, the Battersea Field Club, the Hertfordshire Natural History Society, the Selborne Society (Hampstead Branch), and the Croydon Eclectic Society.

Applications by Local Societies for the loan of the Duplicate Collection of prints or slides should be made to the Secretary. A descriptive account can be lent. The carriage and the making good of any damage to slides or prints are the only expenses to be borne by the borrowing society.

The Committee recommend that they be reappointed, without a grant, and that Professor J. Geikie be reappointed Chairman, and Professor W. W. Watts and Professor S. H. Reynolds be appointed joint Secretaries.

SIXTEENTH LIST OF GEOLOGICAL PHOTOGRAPHS.

FROM AUGUST 12, 1904, TO AUGUST 22, 1908.

This is a list of the geological photographs which have been received and registered by the Secretary of the Committee since the publication of the last Report.

Contributors are asked to affix the registered numbers, as given below, to their negatives for convenience of future reference. Their own numbers are added in order to enable them to do so.

* indicates that photographs and slides may be purchased from the donors or obtained through the address given with the series.

Copies of other photographs desired can, in most instances, be obtained from the photographer direct, or from the officers of the local society under whose auspices the photograph was taken. The cost at which copies may be obtained depends on the size of the print and on local circumstances, over which the Committee have no control.

The Committee *do not assume the copyright of any photographs* included in this list. Inquiries respecting photographs, and applications for permission to reproduce them, should be addressed to the photographers direct.

Copies of photographs should be sent *unmounted* to

Professor S. H. REYNOLDS,
University College, Bristol,

accompanied by descriptions written on a form prepared for the purpose, copies of which may be obtained from him.

The size of photographs is indicated as follows :—

L = Lantern size.	1/1 = Whole-plate.
1/4 = Quarter-plate.	10/8 = 10 inches by 8.
1/2 = Half-plate.	12/10 = 12 inches by 10, &c.

E. signifies Enlargements.

LIST I.

ACCESSIONS IN 1904 TO 1908.

ENGLAND.

CHESHIRE.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

Regd. No.				
4298	(7290)	Storeton Quarries. .	. Fossil Footprints.	1906.
4299	(7291)	,, .	. ,,	,,
4300	(7287)	,, .	. ,,	,,
4301	(7288)	,, .	. ,,	,,
4302	(7289)	,, .	. ,,	,,
4303	(7296)	,, .	. ,,	,,
4304	(7299)	,, .	. ,,	,,
4305	(7293)	,, .	,,	,,
4306	(7294)	,, .	. ,,	,,
4307	(7298)	,, .	. ,,	,,
4308	(7295)	,, .	. ,,	,,
4309	(7297)	,, .	. ,,	,,

CORNWALL.—* *Photographed by* G. V., R. H., *and* HAROLD PRESTON, *Alverne House, Penzance.* 1/1.

Regd. No.		
4310	( ) Trewavas Head, Mount's Bay.	Granite veins in slate. 1905.
4311	( ) Trewavas Head, Mount's Bay.	,, ,, ,,
4312	( ) Trewavas Head, Mount's Bay.	,, ,, ,,
4313	( ) Trewavas Head, Mount's Bay.	,, ,, ,,
4314	( ) Trewavas Head, Mount's Bay.	,, ,, ,,
4315	( ) Gurnard's Head, Zennor.	Hornblende rock and slaty felspar rock?
4316	( ) ,, ,,	,, ,,
4317	(10) St. Loy Cove, St. Buryan. .	Raised beach and water-worn granite. 1906.
4318	(9) ,, ,, .	Raised beach and water-worn granite. 1906.
4319	(8) ,, ,, .	Raised beach and water-worn granite. 1906.
4320	(11) Perranuthnoe, Mount's Bay.	Earth cliffs, encroached on by sea. 1906.
4321	(1) Gwithian Cliffs, St. Ives Bay.	Earth cliffs and raised beach. 1906.
4322	(2) ,, ,,	,, ,, ,,
4323	(3) ,, ,,	Raised beach and consolidated sand. 1906.
4324	(4) ,, ,,	Detached mass of consolidated sand, resting on Devonian slate. 1906.
4325	(7) ,, ,,	Contorted and faulted Devonian slate. 1906.
4326	(5) ,, ,,	Contorted Lower Devonian slate. 1906.
4327	(6) ,, ,,	,, ,, ,,

* *Photographed by* F. GREENWOOD, 5 *St. Mary's Gate, Rochdale.* 1/2.

4328	(224) Porth, near Newquay .	Blowing-hole. 1905.
4329	(225) Fistral Bay, near Newquay.	Raised beach. 1905.

Photographed by L. H. COOKE, *Imperial College of Science and Technology, S.W.* 5/4.

4330	( ) Tywarnhaile Mine, near Redruth.	Junction of two lodes.

DERBYSHIRE.—*Photographed by* J. W. JACKSON, *Manchester Museum, Victoria University, Manchester.* 1/4.

4331	(71) Quarry in Bradwell Dale .	Peculiar erosion in Carboniferous Limestone. 1905.

Photographed by T. U. SIMONSON, *and presented by* A. YOUNG, 45 *Hastings Road, Millhouses, Sheffield.* 1/2.

4332	( ) Froggatt Edge, near Chatsworth.	Weathered Millstone Grit. 1904.
4799	( ) The Eagle Stone, Curbar Edge, Baslow.	,, ,, ,,

Photographed by GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

Regd. No.		
4333	(7319) The Winnats, near Castleton.	Gorge in Carboniferous Limestone. 1906.
4334	(7328) Ravenstor, Miller's Dale .	Carboniferous Limestone and Toadstone. 1906.
4335	(7329) ,, ,, .	Carboniferous Limestone resting on Toadstone. 1906.
4336	(7330) Old Marble Quarry, Tideswell Dale.	Spheroidal structure in Dolerite. 1906.
4337	(7332) Opposite Old Marble Quarry, Tideswell Dale.	Laminated Carboniferous Limestone under sill. 1906.
4338	(7333) Opposite Old Marble Quarry, Tideswell Dale.	Corals in Carboniferous Limestone. 1906.
4339	(7334) Opposite Old Marble Quarry, Tideswell Dale.	Fault in Carboniferous Limestone. 1906.
4340	(7335) Opposite Old Marble Quarry, Tideswell Dale.	Intrusive Dolerite above Carboniferous Limestone. 1906.
4341	(7339) Black Rocks, near Cromford.	Weathered Millstone Grit. 1906.
4342	(7340) Black Rocks, near Cromford.	,, ,, ,,
4343	(7345) Shothouse Spring, near Grange Mills.	Bedded tuff. 1906.
4344	(7347) Grange Mills, near Cromford.	Spheroidal structure in volcanic 'neck.' 1906.
4345	(7349) Longcliffe Sandpit, near Brassington.	Large pocket of sand in Carboniferous Limestone. 1906.
4346	(7350) Longcliffe Sandpit, near Brassington.	Large pocket of sand in Carboniferous Limestone. 1906.
4347	(7352) Longcliffe Sandpit, near Brassington.	Large pocket of sand in Carboniferous Limestone. 1906.
4348	(7353) Longcliffe Sandpit, near Brassington.	Large pocket of sand in Carboniferous Limestone. 1906.
4349	(7354) Mam Tor, near Castleton.	Yoredale shales. 1906.

DEVONSHIRE.—*Photographed by* Professor S. H. REYNOLDS, *University College, Bristol.* 1/2 *and* 1/4.

4350	(1) Bathing Place, Ilfracombe. .	Contorted limestone bands. 1903.
4351	(2) ,, ,, .	,, ,, ,,
4352	(3) ,, ,, .	,, ,, ,,
4353	(4) ,, ,, .	Cleaved and contorted grit band. 1903.
4354	(7) ,, ,, .	Contorted and disrupted quartz veins. 1903.
4355	(8) ,, ,, .	Contorted and disrupted quartz veins. 1903.
4356	(9) ,, ,, .	Contorted and disrupted quartz veins. 1903.
4357	(5) Hele Bay, near Ilfracombe. .	Contorted limestone band. 1903.
4358	(6) Quarry, a little W. of Combe Martin on the Ilfracombe road.	Contorted limestone bands. 1903.
4359	(10) E. of Bathing Place, Ilfracombe.	Anticline in cleaved Devonian. 1903.
4360	(11) Rillage Point, Ilfracombe .	Marine erosion of jointed Devonian. 1903.
4361	(12) ,, ,, .	Quartz veins in parallel joints in Devonian. 1903.
4362	(13) Haggington Beach, Ilfracombe.	Joint and bedding caves. 1903.

Regd. No.		
4363	(14) Saunton.	'Head' on consolidated blown-sand in which sea-caves have been excavated. 1903.
4364	(15) ,,	Consolidated blown-sand. 1903.
4365	(16) ,,	False bedding and conglomerate layer in raised beach, or consolidated blown-sand. 1903.
4366	(17) ,,	Consolidated blown-sands resting on Pilton Beds. 1903.
4367	(18) ,,	Consolidated blown-sands resting on Pilton Beds. 1903.
4368	(19) ,,	Large granite boulder underlying consolidated blown-sands. 1903.
4369	(20) ,,	'Drag of the hill.' 1903.
4370	(21) Combe Martin Harbour.	Crumpling of slates by 'drag of the hill.' 1903.

Photographed by R. H. RASTALL, *M.A., Christ's College, Cambridge.* 1/4.

4371	( ) Combe Martin	Folded grit in well-cleaved slate. 1903.
4372	( ) Cliffs W. of Budleigh Salterton.	Pebble-beds and sandstone. 1903.

Photographed by Mr. FRIENDSHIP *and presented by* E. A. NEWELL ARBER, *Trinity College, Cambridge.* 1/1.

4373	( ) Broadbench Cove, N. of Welcombe Mouth.	Contorted shales and sandstones, Upper Carboniferous. 1906.

Photographed by F. G. COLLINS, *Daisy Mount, Polsloe Road, Exeter, and presented by* C. DAVIES SHERBORN. 1/4.

4374	(1) Posbury Quarry.	Junction of agglomerate with compact rock. 1905.
4375	(2) ,, ,,	Weathered face of agglomerate. 1905.

DURHAM.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2 *and* 1/4.

4790	(6891) Above High Force, Teesdale	Whin sill on altered limestone. 1905.
4791	(6893) Widdy Bank, Teesdale.	Mica-trap dyke. 1905.
4792	(6894) Cauldron Snout, Teesdale.	Whin sill. 1905.
4793	(6895) Falcon Clints, Teesdale.	Whin sill on basement beds of Carboniferous Limestone. 1905.
4794	(6896) ,, ,, ,,	Whin sill on basement beds of Carboniferous Limestone. 1905.

Photographed by H. PICKLES, *The Modern School, Leeds.* 1/1.

4795	( ) Quarry, near Hudeshope Beck.	Drift over Carboniferous Limestone. 1906.

Photographed by Dr. D. WOOLACOTT, *Armstrong College, Newcastle-on-Tyne.* 1/2.

4796	( ) Claxheugh, 2 miles from Sunderland.	Landslip in Magnesian Limestone, resting on Yellow Sands. 1905.

Photographed by J. A. SMYTHE, *Armstrong College, Newcastle-on-Tyne.* 1/4.

Regd. No.		
4797	(24a) Coast, nr Whitburn Colliery.	Stack of partly brecciated Magnesian Limestone. 1904.
4798	(24b) Coast, ½ mile S. of Whitburn Colliery.	Flat-topped sea-caves in Magnesian Limestone. 1904.

GLOUCESTERSHIRE.—*Photographed by* Professor S. H. REYNOLDS, *University College, Bristol.* 1/4 *and* 1/2.

4376	(1) Lilliput Cutting, Chipping Sodbury.	Weathered concretionary beds in Carboniferous Limestone, S2. 1903.
4377	(2) Lilliput Cutting, Chipping Sodbury.	Weathered concretionary beds in Carboniferous Limestone, S2. 1903.
4378	( ) East end of Sodbury Tunnel.	Forest marble over Great Oolite. 1902.
4379	( ) Cutting W. of Chipping Sodbury Station.	Upper Rhætic and Lower Lias. 1902.
4380	( ) Cutting W. of Chipping Sodbury Station.	Rhætic Shale on eroded Old Red Sandstone. 1902.
4381	(5) Shirehampton. . .	Syncline in Old Red Sandstone. 1905.
4382	(6) "	Keuper on Old Red Sandstone. 1905.
4383	(7) "	Disturbed Old Red Sandstone covered by Keuper. 1905.
4384	(9) "	Faulted Keuper unconformably on Old Red Sandstone. 1905.
4385	(10) "	Syncline in Old Red Sandstone. 1905.
4386	(11) "	Disturbed Old Red Sandstone overlain by Keuper. 1905.
4387	(72) Westleton Quarry, Chipping Campden.	Annelid borings in L. Freestone. 1904.
4388	(73) Westleton Quarry, Chipping Campden.	Annelid borings in L. Freestone. 1904.
4389	(69) Wick Rocks, near Warmley.	Highly ochreous Keuper Marl. 1904.
4390	(70) " "	Coal-seam Millstone Grit. 1904.
4391	(71) " "	Mammillated top of Millstone Grit. 1904.

Photographed by Miss M. S. JOHNSTON, *Hazelwood, Wimbledon Hill.* 1/4

4392	( ) Bredon Station, near Tewkesbury.	Northern Drift on Lias Clay. 1904.

HAMPSHIRE.—*Photographed by* C. H. B. EPPS, *M.A.*, 95 *Upper Tulse Hill, S.W.* 1/2.

4393	(1152) Chalk Pit, near Hensting Farm, near Owslebury.	Radiating joints in chalk, round gravel filling underground watercourse, 1905.
4394	(1153) Chalk Pit, near Hensting Farm, near Owlesbury.	Cylindrical, transverse, and radiating joints in chalk. 1905.
4395	(1154) Chalk Pit, near Hensting Farm, near Owlesbury.	Radiating joints in chalk. 1905.

Photographed by J. A. SMYTHE, *Armstrong College, Newcastle-on-Tyne.* 1/4.

4396	(24*c*) Blackgang Chine, Isle of Wight.	Lower Greensand. 1903.

HEREFORDSHIRE.—*Photographed by* J. HOPKINSON, *Westwood, Watford.* 1/4.

4397	(19) Mocktree Hill Quarry, near Leintwardine.	Fault in Aymestry Limestone. 1904.

KENT.—*Photographed by* C. C. BUCKINGHAM, 108 *High Street, Godalming.* 1/2.

Regd. No.		
4398	(130) Elham Nailbourne, near Bekesbourne	Well Chapel Springs; seldom dry. 1904.
4399	(131) Elham Nailbourne, near Bekesbourne.	Springs at usual head of Lesser Stour. 1904.
4400	(132) Elham Nailbourne, near Bekesbourne.	Bourne flowing. Jan. 1904.
4401	(133) Elham Nailbourne, near Bekesbourne.	Same view; bourne dry. Dec. 1904.
4402	(134) Elham Nailbourne, near Bekesbourne.	Bourne flowing. Jan. 1904.
4403	(135) Elham Nailbourne, near Bekesbourne.	Same view; bourne dry. Dec. 1904.
4404†	(136) Elham Nailbourne, near Bekesbourne.	Bourne flowing. Jan. 1904.
4405§	(137) Elham Nailbourne, near Bekesbourne.	Same view; bourne dry. Jan. 1905.
4406†	(138) Elham Nailbourne, near Bekesbourne.	Bourne flowing. Jan. 1904.
4407¶	(139) Elham Nailbourne, near Bekesbourne.	Same view; bourne dry. June 1905.
4408	(140) Elham Nailbourne, near Bekesbourne.	The Lake, Bourne Park. Jan. 1904.
4409	(142) Elham Nailbourne, near Bekesbourne.	Nailbourne flowing into lake. Jan. 1904.
4410	(143) Elham Nailbourne, near Bekesbourne.	Same view; bourne dry. Jan. 1905.
4411	(144) Elham Nailbourne, Bourne Park.	Cold Bath Spring; flowing. Jan. 1904.
4412	(145) Elham Nailbourne, Bourne Park.	Same view; bourne dry. Feb. 1905.
4413	(146) Elham Nailbourne, near Bishopsbourne.	Spring in Bourne Park. June 1904.
4414	(147) Elham Nailbourne, near Bishopsbourne.	Same view; bourne dry. Dec. 1904.
4415	(148) Elham Nailbourne, near Bishopsbourne.	Cessation of flow. June 1904.
4416	(149) Elham Nailbourne, at Barham.	Bourne flowing. Jan. 1904.
4417	(150) Elham Nailbourne at Barham.	Same view; bourne dry. Jan. 1905.
4418	(151) Elham Nailbourne at Barham.	Bourne flowing. Jan. 1904.
4419	(152) Elham Nailbourne at Barham.	Same view; bourne dry. Jan. 1905.
4420	(153) Elham Nailbourne .	Bourne flowing. Jan. 1904.
4421	(154) Elham Nailbourne .	Same view; bourne dry. March 1905.
4422	(155) Elham Nailbourne, Barham.	Water issuing in roadway. May 1904.
4423	(156) Elham Nailbourne, South Barham.	Bourne flowing. Jan. 1904.
4424	(157) Elham Nailbourne, South Barham.	Same view; bourne dry. March 1905.
4425	(158) Elham Nailbourne, Lyminge.	Springs in higher part of valley. June ?
4426	(159) Petham Nailbourne.	Usual saturation level, Shalmsford Street. June ?

† Photographed by F. S. Snell, 8 Guildhall Street, Canterbury.
§ Photographed by W. E. Smith, 11 Broad Street, Canterbury.
¶ Photographed by H. Divers, Burgate Street, Canterbury.

Regd. No.			
4427	(160)	Petham Nailbourne . .	Hollow at Perry Farm; reached by bourne in 1892 and 1897. June 1904.
4428	(161)	,, . .	Flowing along road. March 1904.
4429	(162)	,, . .	Same road dry. July 1904.
4430†	(163)	,, . .	100 yards from source. March 1904.
4431	(164)	,, . .	Same view; bourne dry. July 1904.
4432	(165)	,, . .	Source of 1904 flow; flowing. June 1904.
4433§	(166)	,, . .	Same view; bourne dry. Nov. 1904.
4434	(167)	,, . .	Source of 1904 flow. March 1904.
4435	(168)	,, . .	Same view; bourne dry. June 1905.
4436	(173)	St. Margaret's Bay . .	Before cliff-fall. Jan. 1905. (Copy of old photograph.)
4437†	(174)	,, . .	After cliff-fall. Jan. 1905.
4438	(175)	,, . .	Gap caused by cliff-fall. Jan. 1905.
4439	(176)	,, . .	,, ,, ,,
4440	(177)	,, . .	Cliff-fall and *débris*. Jan. 1905.

LANCASHIRE.—*Photographed by* J. W. JACKSON, *Manchester Museum, Victoria University, Manchester.* 1/4.

4441	(114)	Silverdale Shore . .	Tidal bore in River Kent. 1905.
4442	(165)	,, . .	Erosion of 'Salt-marsh.' 1905.

* *Photographed by* F. GREENWOOD, 5 *St. Mary's Gate, Rochdale.* 1/2.

4443	(54)	Fairies' Chapel, Healey Dell, Rochdale.	Stream erosion. 1897.

LEICESTERSHIRE.—*Photographed by the late* G. HODSON, *M.Inst.C.E., Loughborough.* 10/8.

4444	(11)	Blackbrook Valley, Charnwood Forest.	From near the Oaks Church. 1904.
4445	(10)	Blackbrook Valley, Charnwood Forest.	Moult Hill. 1904.
4446	(9)	Blackbrook Valley, Charnwood Forest.	Moult Hill and One Barrow. 1904.
4447	(8)	Blackbrook Valley, Charnwood Forest.	One Barrow Quarry. 1904.
4448	(7)	Blackbrook Valley, Charnwood Forest.	Site of reservoir dam. 1904.
4449	(4)	Blackbrook Valley, Charnwood Forest.	Old canal dam. 1900.
4450	(2)	Blackbrook Valley, Charnwood Forest.	View up valley from old canal dam. 1899.
4451	(3)	Blackbrook Valley, Charnwood Forest.	View down valley from old canal dam. 1899.
4452	(1)	Blackbrook Valley, Charnwood Forest.	Looking up valley at old canal dam. 1899.
4453	(5)	Blackbrook Valley, Charnwood Forest.	Looking up valley at old canal dam. 1900.
4454	(6)	Blackbrook Valley, Charnwood Forest.	Looking up valley at site of old canal dam, just removed. ? 1901.
4455	(2)	Blackbrook Valley, Charnwood Forest.	East trench for dam. 1902.
4456	( )	Blackbrook Valley, Charnwood Forest.	The reservoir dam from west. 1904.
4457	(3)	Blackbrook Valley, Charnwood Forest.	Quarry north of the dam (Blackbrook Grits). 1904.
4458	(1)	One Barrow Quarry, Blackbrook.	Grit in Blackbrook beds. 1904.

† Those marked thus by F. S. Snell, 8 Guildhall Street, Canterbury.
§ Photographed by W. E. Smith, 11 Broad Street, Canterbury.

LINCOLNSHIRE.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

Regd. No.		
4459	(6733) Beesby Top, near Wold Newton.	Glacial overflow valley. 1905.
4460	(6735) Wold Newton Valley, from Beesby Top end.	Glacial dry valley. 1905.
4461	(6736) Wold Newton Valley .	Dry glacial valley. 1905.
4462	(6739) Hatcliffe	Glacial dry valley. 1905.
4800	(6746) Deepdale Firs, Thorganby.	,, ,,
4463	(6777) Deepdale Firs, Berwell, near Louth.	,, ,,
4464	(6771) Bully Hill, near Tathwell.	,, ,,
4465	(6773) Orgath Valley, near Tathwell.	,, ,,
4466	(6774) Orgath Valley, near Tathwell.	,, ,,
4467	(6749) Hubbard's Valley, Louth .	River Ludd. 1905.
4468	(6780) Great Covert Valley, Walmsgate, near Louth.	Glacial dry valley. 1905.
4469	(6781) Great Covert Valley, Walmsgate, near Louth.	,, ,,
4470	(6747) Chalk-pit, Boswell, N. Elkington.	Upper Chalk. 1905.
4471	(6754) Gravel-pit, Welton Dale, S Elkington, Louth.	Chalky and decalcified gravels covered by boulder-clay. 1905.
4472	(6755) Sand-pit, South Elkington Hall.	Current-bedded gravel, chalky gravel, and sands. 1905.
4473	(6758) Clay-pit, Charles Street, Louth.	Two glacial clays separated by sand and gravel. 1905.
4474	(6759) Chalk-pit, Grimsby Road, Louth.	Lower Chalk, with pink bands at base. 1905.
4475	(6760) W. end Withcall Tunnel, G.N.R., S. side.	Lower Chalk, on Red Chalk. 1905.
4476	(6761) W. end Withcall Tunnel, G.N.R., N. side.	Red chalk and Carstone. 1905.
4477	(6763) Sand-pit, Donnington-on-Bain.	Spilsby Sand and Claxby Ironstone. 1905
4478	(6764) Cutting on G.N.R., near Donnington-on-Bain.	Spilsby Sandstone. 1905.
4479	(6765) Cutting on G N.R., near Donnington-on-Bain.	,, ,,
4480	(6772) Gravel-pit, Orgarth Farm, Tathwell.	Pocket of boulder-clay in gravel. 1905.
4481	(6785) E. of North Willingham .	Tealby Limestone. 1905.
4482	(6786) Clay-pit, Market Rasen .	Lower Kimeridge Clay and blown sand. 1905.
4483	(6787) ,, ,, .	Lower Kimeridge Clay and blown sand. 1905.
4484	(6788) Claxby, near Market Rasen.	Ironstone, top of Spilsby Sandstone.

NORFOLK.—*Photographed by* G. HASTINGS, 15 *Oak Lane, Bradford.* 1/2 *and* 1/4.

4485	( ) Cromer Cliffs	Fine contortion in Drift. 1904.
4486	( ) ,, ...	Small contortions in Drift. 1904.
4487	( ) ,, ...	Chalk boulders in contorted Drift. 1904.
4488	( ) ,, ...	Augen of sand in boulder-clay. 1904.
4489	( ) ,, ...	Boulder-clay in sand. 1904.
4490	( ) ,, ...	Lines of flint in chalk-boulder. 1904.
4491	( ) ,, ...	Effect of wind on drifting sand. 1904.

Regd No.		
4492	( ) Cromer Cliffs . . .	Fan deltas on Trimingham Beach. 1904.
4493	( ) „ . . .	Contorted Drift resting on Chalk Headland. 1904.

NORTHUMBERLAND.—*Photographed by* J. A. SMYTHE, *Armstrong College, Newcastle-on-Tyne.* 1/4.

4496	(24 L) Bamburgh Castle . .	Whin sill overstepping Bernician sandstones. 1904.
4497	(24 M) Dunstanburgh . .	Whin sill resting on baked shale. 1904.
4498	(24 N) Cullernose Point . .	Whin sill and Bernician limestones. 1904.
4499	(24 O) The Lakes, near Bardon Mill.	Whin sill escarpment. 1903.
4500	(24 P) ½ S. of Cullernose Point .	Reversed fault shifted by normal fault. 1904.

NOTTINGHAMSHIRE.—*Photographed by* Professor J. W. CARR, *University College, Nottingham.* 1/2.

4501	( ) Gilt Hill, N.W. of Kimberley.	Faults in coal-seam.

SHROPSHIRE.—*Photographed by* Professor S. H. REYNOLDS, *University College, Bristol.* 1/4.

4502	(24) The Stiperstones. . .	Two of the Quartzite crags. 1904.
4503	(25) „ . .	One of the Quartzite crags. 1904.
4504	(26) „ . .	„ „ „
4505	(27) Weo Edge.	Aymestry Limestone escarpment. 1904.

Photographed by E. S. COBBOLD, *Watling House, Church Stretton.* 1/2.

4506	( ) Caer Caradoc. . . .	Brecciated red rocks. 1905.
4507	( ) Caer Caradoc, 'Cave of Caractacus.'	Joints and amygdules in rhyolite. 1905.
4508	( ) 800 yards N.E. of Church Stretton Station.	Small faults in Drift sand covered by stony clay. 1905.

Photographed by J. HOPKINSON, *Weetwood, Watford.* 1/4.

4509	(18) Quarry, Titterstone Clee Hill.	Dolerite below Coal Measures. 1904.

SOMERSET.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

4510	(7247) Cheddar.	Carboniferous Limestone cliffs. 1906.
4511	(7250) „	„ „ „
4512	(7251) „	„ „ „
4513	(7257) „	„ „ „
4514	(7259) „	„ „ „
4515	(7252) „	„ „ „
4516	(7255) „	„ „ „
4517	(7258) „	„ „ „

Photographed by Professor S. H. REYNOLDS, *University College, Bristol.* 1/2 and 1/4.

4518	(05, 63) Wookey.	Mouth of Wookey Cave. 1905.
4519	(05, 62) „	Hyæna den. 1905.
4520	(06, 9) Cheddar. . . .	Rock fall. Feb. 4, 1906.
4521	(06, 10) „	„ „ „
4522	(06, 11) „	„ „ „

Regd. No.		
4523	(06, 12) Cheddar . . .	Rock fall. Feb. 4, 1906.
4524	(06, 13) „	„ „ „
4525	(06, 14) „	„ „ „
4526	(06, 15) „	Outflow of stream. 1906.
4527	(06, 16) „	„ „
4528	(05, 12) S. of Battery Point, Portishead.	Folds in lower beds of Carboniferous Limestone (K_2). 1905.
4529	(05, 13) S. of Battery Point, Portishead.	Folds in lower beds of Carboniferous Limestone (K_2). 1905.
4530	(05, 14) S. of Battery Point, Portishead.	Folds in lower beds of Carboniferous Limestone (K_2). 1905.
4531	(05, 16) S. of Battery Point, Portishead.	Folds in lower beds of Carboniferous Limestone (K_2). 1905.
4532	(05, 1) Coast N. of Walton, Clevedon.	Dolomitic Conglomerate resting unconformably on Old Red Sandstone. 1905.
4533	(05, 2) Coast N. of Walton, Clevedon.	Dolomitic Conglomerate resting unconformably on Old Red Sandstone. 1905.
4534	(05, 2*x*) Coast N. of Walton, Clevedon.	Dolomitic Conglomerate resting unconformably on Old Red Sandstone. 1905.
4535	(05, 3) Coast N. of Walton, Clevedon.	Dolomitic Conglomerate resting unconformably on Old Red Sandstone. 1905.
4536	(05, 4) Coast N. of Walton, Clevedon.	Current-bedding in Old Red Sandstone. 1905.
4537	( ) Coast S. of Black Nore, Portishead.	Current-bedding in Old Red Sandstone. 1906.
4538	(06, 1) Coast S. of Black Nore, Portishead.	Current-bedding in Old Red Sandstone. 1906.
4539	(06, 2) Coast S. of Black Nore, Portishead.	Current-bedding in Old Red Sandstone. 1906.
4540	(06, 3) Near Black Nore, Portishead.	Undercut cliff of Dolomitic Conglomerate. 1906.
4541	(06, 4) Coast S. of Black Nore, Portishead.	Dolomitic Conglomerate, unconformably on Old Red Sandstone. 1906.
4542	(06, 5) Coast S. of Black Nore, Portishead.	Dolomitic Conglomerate, unconformably on Old Red Sandstone. 1906.
4543	(06, 6) Coast S. of Black Nore, Portishead.	Dolomitic Conglomerate, unconformably on Old Red Sandstone. 1906.
4544	(06, 7) Near Black Nore, Portishead.	Cliff of Dolomitic Conglomerate. 1906.
4545	(61) Vallis, near Frome. . .	Ragstones (Inferior Oolite), unconformable on Carboniferous Limestone. 1904.
4546	(62) „ „ . .	Ragstones (Inferior Oolite), unconformable on Carboniferous Limestone. 1904.
4547	(63) „ „ . .	Ragstones (Inferior Oolite), unconformable on Carboniferous Limestone. 1904.
4548	(64) „ „ . .	Ragstones (Inferior Oolite), unconformable on Carboniferous Limestone. 1904.
4549	(65) Holwell, near Frome. .	Triassic material filling fissures in Carboniferous Limestone. 1904.
4550	( ) Quarry E. of Worle Hill, Weston-super-Mare.	Folded Carboniferous Limestone, Seminula zone.
4551	(66) Moon's Hill, Stoke Lane, Mendips.	Quarry in pyroxene andesite. 1904.
4552	(67) Sunnyhill Quarry, Stoke Lane, Mendips.	Volcanic series. 1904.
4553	(68) Sunnyhill Quarry, Stoke Lane, Mendips.	„ „

STAFFORDSHIRE.—*Photographed by* J. T. STOBBS, *Dunelm, Basford Park Stoke-on-Trent.* 1/2.

4554	( ) Weston Sprink, near Longton.	Marine band and hematite band in Coal Measures.

SUFFOLK.—*Photographed by* JAMES CARVER, *Unthank Road, Norwich.* 1/2.

Regd. No.			
4494	( )	Pakefield, near Lowestoft. .	Destruction of cliffs by sea. 1903.
4495	( )	Lowestoft.	Destruction of sea-wall. 1903.

SURREY.—*Photographed by* J. H. BALDOCK, *Overdale, St. Leonards Road, Croydon.* 1/2.

4555	(04, 63)	Honor Oak . .	Landslip from N.E. 1904.
4556	(04, 66)	„ . . .	Landslip from near S.W. end. 1904.
4557	(04, 67)	„ . . .	Effect of hedge on slipping of London Clay. 1904.
4558	(04, 64)	„ . . .	Landslip, S.W. end. 1904.
4559	(04, 65)	„ . . .	Effect of landslip on house entrance. 1904.

Photographed by N. F. ROBARTS, 23 *Oliver Grove, South Norwood.* 1/4.

4560	(688)	Brickfield N. of Cheam Church.	Junction of Woolwich and Reading Beds with Thanet Sands. 1907.
4561	(689)	Brickfield N. of Cheam Church.	Junction of Woolwich and Reading Beds with Thanet Sands. 1907.
4562	(690)	Brickfield N. of Cheam Church.	Junction of Woolwich and Reading Beds with Thanet Sands. 1907.
4563	(691)	Springclose Brickfield, Cheam.	25 feet of Reading Beds. 1907.
4564	(692)	Springclose Brickfield, Cheam.	„ „
4565	(693)	Springclose Brickfield, Cheam.	„ „

SUSSEX.—*Photographed by* Dr. HORACE T. BROWN, *F.R.S.*, 52 *Nevern Square, S.W.* 5/4.

4566	( )	Bexhill.	Erosion of water-gullies in bed of clay. 1905 ?
4567	( )	„	Erosion of water-gullies in bed of clay. 1905 ?
4568	( )	„	Erosion of water-gullies in bed of clay. 1905 ?
4569	( )	„	Erosion of water-gullies in bed of clay. 1905 ?
4570	( )	„	Erosion of water-gullies in bed of clay. 1905 ?

Photographed by G. W. MOORE, *Dornton Road, Croydon. Contributed by* W. WHITAKER, *F.R.S.* 1/4.

4571	( )	Eridge Park. . . .	Open joint in Tunbridge Wells Sand. 1905.

WESTMORLAND.—*Photographed by* Professor E. J. GARWOOD, *M.A.*, *University College, London.* 1/1.

4572	(2)	Vale of Eden. . . .	Weathered quartz veins in Penrith Sandstone.
4573	(3)	„ . . .	Weathered quartz veins in Penrith Sandstone.
4576	(1)	Hilton Beck, near Appleby. .	Waterfall over Magnesian Limestone.

Photographed by GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

Regd. No.		
4574	(6500) Arnside	Folded Carboniferous Limestone. 1904.
4575	(6501) ,, ...	,, ,, ,,

YORKSHIRE.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

4577	(6959) North side of Castle Hill, Scarborough.	Corallian Beds. 1905.
4578	(6962) South side of Castle Hill, Scarborough.	Middle Corallian Beds. 1905.
4579	(7387) Marine Drive, Castle Hill, Scarborough.	Oxford Clay and Corallian Beds. 1906.
4580	(7388) Marine Drive, Castle Hill, Scarborough.	,, ,, ,,
4581	(6648) Gravel-pit, Middleton on the Wolds.	Moraine gravels and sands. 1904.
4582	(6650) Holme Dale, near Middleton on the Wolds.	Glacial dry valley. 1905.
4583	(6651) Holme Dale, near Middleton on the Wolds.	,, ,, ,,
4584	(7355) Sand-pit, Deighton, York	Section in moraine. 1906.
4585	(7356) ,, ,, ,,	,, ,, ,,
4586	(6547) Ganister Quarry, Meanwood Valley, Leeds.	Folds in Ganister. 1904.
4587	(4658) Ganister Quarry, Meanwood Valley, Leeds.	,, ,, ,,
4588	(6705) Ganister Quarry, Meanwood Valley, Leeds.	Folds in Ganister. 1905.
4589	(6645) Ganister Quarry, Meanwood Valley, Leeds.	Stigmarian root. 1904.
4590	(6889) High Force, Teesdale .	Whin sill in Carboniferous Limestone. 1905.
4591	(6890) ,, ,, .	Looking down stream. 1905.
4592	(6892) Widdybank, near Pencil Mill, Upper Teesdale.	Ordovician Rocks. 1905.
4593	(6897) Thistle Green, Cronkley Fell, Teesdale.	Saccharoid limestone, resting on Whin Sill. 1905.
4594	(6898) Thistle Green, Cronkley Fell, Teesdale.	Saccharoid limestone, resting on Whin Sill. 1905.
4595	(A) Buttertubs Pass, Hawes to Swaledale.	Chasm in Carboniferous Limestone. 1906.
4596	(B) Buttertubs Pass, Hawes to Swaledale.	,, ,, ,, ,,
4597	(C) Buttertubs Pass, Hawes to Swaledale.	,, ,, ,, ,,
4598	(D) Buttertubs Pass, Hawes to Swaledale.	,, ,, ,, ,,
4599	(E) Near Keld, Swaledale .	Fault in Yoredale Beds. 1906.
4600	(7012) Trollers Gill . . .	Gorge in Carboniferous Limestone. 1906.
4601	(7014) ,, ...	,, ,, ,, ,,
4602	(7015) Near Trollers Gill . .	Formation of delta. 1906.
4603	(6902) Near Wemmergill, Lunedale.	Dry glacial overflow valley. 1905.
4604	(6994) Angram, Upper Nidderdale	Yoredale shales and limestones. 1906.
4605	(6998) ,, ,,	Folding and faulting of basement Yoredale Beds. 1906.
4606	(7000) Goydon Pot, R. Nidd, above Lofthouse.	Entrance to 'Pot.' 1906.

Regd. No.		
4607	(7004) Nidd Head, below Lofthouse.	Issue of water from Manchester Pot and Goydon Pot. 1906.
4608	(6991) Lolley Scar Quarry, near Ramsgill, Nidderdale.	Upper Yoredale series. 1906.
4609	(6993) Limley, Upper Nidderdale.	Upper Yoredale limestone. 1906.
4610	(7006) Greenhow Quarry, near Pateley Bridge.	Carboniferous Limestone. 1906.
4611	(7007) Greenhow Quarry, near Pateley Bridge.	" " "
4612	(6845) Hambleton Quarry, near Bolton Abbey Station.	Folded Yoredale limestone. 1905.
4613	(6846) Hambleton Quarry, near Bolton Abbey Station.	" " " "

Photographed by G. H. RODWELL, *Brooklyn Villa, New Manston, near Leeds.* 1/2.

4614	( ) Mulgrave Castle Inn, 1½ mile N. of Whitby.	Destroyed by sea about 1885 or 1886. 1883.

Photographed by Professor E. J. GARWOOD, *M.A., University College, London.* 1/1.

4615	(4) Scalber, near Settle .	'Knoll-reefs,' Craven fault, and Lower Scar Limestone.
4616	(5) " " .	'Knoll-reefs,' Craven fault, and Lower Scar Limestone.

Photographed by F. GREENWOOD, 5 *St. Mary's Gate, Rochdale.* 1/2.

4617	(12) Hell Hole, Heptonstall .	1902.

WALES.

BRECKNOCK.—*Photographed by* Miss F. NEALE, *Lynwood Park Road, Penarth.* 1/4. *Described by* F. T. HOWARD, *M.A.*

4618	( ) Middle Clyngwyn Falls, 2½ miles from Pont Neath Fychan.	Falls due to faulting. 1901.
4619	( ) Middle Clyngwyn Falls, 2½ miles from Pont Neath Fychan.	Falls due to faulting. 1901. (?)
4620	( ) Upper Clyngwyn Falls, 2¾ miles from Pont Neath Fychan.	Falls due to faulting of M. shales of Millstone Grit against pebbly grit. (?)
4621	( ) Clyngwyn Falls . . .	Upper part of Middle Falls, due to faulting. 1902.
4622	( ) Lower Clyngwyn Falls, Mellte River.	Due to faulting, which brings shales of Millstone Grit against the pebbly grits. 1901.
4623	( ) Cilhepste Falls, 3 miles N.E. from Pont Neath Fychan.	Falls due to Clyngwyn fault. 1902.
4624	( ) Caer Howel, on R. Hepste, 3 miles from Pont Neath Fychan.	Dry flood-course of underground river. 1904.
4625	( ) Hepste Falls . . .	Due to Clyngwyn fault. 1902.
4626	( ) Pwll-y-Rhyd, 4 miles N. of Pont Neath Fychan.	Chasm along joints in Carboniferous Limestone. 1904.
4627	( ) Cwm Pwll-y-Rhyd . .	Chasm due to strong joints crossing stream at right angle. 1904.
4628	( ) " " . .	Gorge following strong joint in Carboniferous Limestone. 1901.

Regd. No.		
4629	( ) Cwm Pwll-y-Rhyd. . .	Jointed Carboniferous Limestone. 1904.
4630	( ) Ystradfellte. . . .	R. Mellte entering underground channel. (?)
4631	( ) $\frac{2}{3}$ mile S. of Ystradfellte. .	,, ,, ,, ,,
4632	( ) 1 mile S. of Ystradfellte, 19 miles from Brecon.	Outlet of underground stream in Carboniferous Limestone. 1904.
4633	( ) Ysgwd-yr-Eira, 3 miles from Pont Neath Fychan.	Falls due to shale bed in Millstone Grit. 1902.
4634	( ) Ysgwd-yr-Eira, 3 miles from Pont Neath Fychan.	Falls due to shale bed in Millstone Grit. 1902.
4635	( ) Afon Llia, $2\frac{1}{2}$ miles N. of Ystradfellte.	Falls due to hard bands in Old Red Sandstone. 1901.
4636	( ) Ysgwd Gwladys, $\frac{1}{2}$ mile N. of Pont Neath Fychan.	Waterfall due to 12-foot grit in middle shales of Millstone Grit. 1904.
4637	( ) Nant-y-Moch, 17 miles N. of Neath.	Falls due to hard bands in Old Red Sandstone. 1902.
4638	( ) Nant-y-Moch, 17 miles N. of Neath.	Dip valley in Old Red Sandstone. 1902.
4639	( ) Ysgwd Gwladys.	Thin grit in shale division of Millstone Grit. 1902.
4640	( ) $\frac{2}{3}$ mile S. of Ystradfellte .	Gorge of R. Mellte in Carboniferous Limestone. (?)
4641	( ) Pwlldu, 3 miles N. of Pont Neath Fychan.	Bedded Carboniferous Limestone along fault course. 1902.
4642	( ) Sychnant Ravine, Pont Neath Fychan.	Carboniferous Limestone almost vertical. 1902.
4643	( ) Sychnant Ravine, Pont Neath Fychan.	Flood course of Sychnant Brook. 1902.
4644	( ) Sychnant Ravine, Pont Neath Fychan.	Line of fault. 1902.
4645	( ) Craig-y-Dinas, 1 mile from Pont Neath Fychan.	Carboniferous Limestone near overthrust. 1902.
4646	( ) Craig-y-Dinas, 1 mile from Pont Neath Fychan.	Curved Carboniferous Limestone. 1902.

CARNARVONSHIRE.—*Photographed by* C. H. B. EPPS, M.A., 95 *Upper Tulse Hill, S.W.* 5/3.

4647	(87) Wood below road from Penmorfa to Brynkir, near large road-metal pit.	Transgression of sill across slaty beds. 1902.

Photographed by L. H. COOKE, *Imperial College of Science and Technology, S.W.* 5/4.

4648	( ) Aberllyn Mine, Llanrwst. .	Stalactites grown in six years.

Photographed by Messrs. FRITH & Co. ; *presented by* Professor W. W. WATTS. 1/1.

4649	Llanberis.	Slate Quarries.

MERIONETHSHIRE.—*Photographed by* Professor S. H. REYNOLDS, *University College, Bristol.* 1/4.

4650	(31) Mynydd-y-Gader, Dolgelly.	Weathered nodular rhyolite. 1902.
4651	(32) ,, ,,	,, ,, ,,
4652	(33) ,, ,,	,, ,, ,,
4653	(34) ,, ,,	,, ,, ,,
4654	(35) ,, ,,	Banded rhyolite. 1902.
4655	(36) ,, ,,	,, ,,
4656	(37) ,, ,,	,, ,,

Regd. No.			
4657	(38)	Mynydd-y-Gader, Dolgelly.	Banded rhyolite. 1902.
4658	(39)	" "	Weathered tuff. 1902.
4659	(40)	" "	Weathered coarse tuff. 1902.
4660	(41)	" "	Coarse tuff. 1902.
4661	(43)	" "	" "
4662	(42)	" "	" "
4663	(44)	" "	" "
4664	(45)	" "	" "
4665	(29)	" "	Frost-weathering of diabase. 1902.
4666	(30)	" "	" " "
4668	(46)	" "	Veins in diabase. 1902.
4669	(47)	" "	" "
4670	(48)	" "	End of vein in diabase. 1902.
4671	(49)	S. of western end, Mynydd-y-Gader.	Relations of bedding and cleavage in grits and slates. 1902.
4672	(50)	S. slopes, Mynydd-y-Gader.	Erratic block. 1902.
4673	(51)	Mynydd-y-Gader . .	Erratic of diabase on rhyolite. 1902.
4674	(52)	" . .	Erratic of diabase. 1902.
4675	(53)	" . .	Erratic resting on coarse tuff. 1902.
4676	(55)	" . .	Erratic. 1902.
4677	(54)	" . .	Glaciation of tuff and greenstone. 1902.
4678	(56)	" . .	Glaciated country. 1902.
4679	(57)	W. of Graig, Dolgelly .	Roche moutonnée. 1902.
4680	(58)	" " . .	" "
4681	(59)	" " . .	" "
4682	(60)	" " . .	" "

Photographed by PICTORIAL STATIONERY CO. *and presented by* Professor W. W. WATTS.

4667	( )	Cader Idris.	Colour photograph of main cliff over Llyn-y-Gader.

MONTGOMERYSHIRE.—*Photographed by* Professor S. H. REYNOLDS, *University College, Bristol.* 1/4.

4683	(23)	Corndon, from the E.	Undercut and overcut sides. 1904.
4684	(22)	Corndon from the S.E.	Undercut side of Laccolite. 1904.

RADNORSHIRE.—*Photographed by* Professor S. H. REYNOLDS, *University College, Bristol.* 1/4.

4685	(28)	Llandrindod . . .	Large erratic. 1904.

SCOTLAND.

ARGYLLSHIRE.—*Photographed by* A. T. METCALFE, *Southwell, Notts.* 1/4.

4686	(G.S. 1)	Carsaig, Mull. . .	Jurassic rocks capped by basalt. 1904.
4687	(G.S. 2)	Ross of Mull. . .	Wave-worn granite. 1904.
4688	(G.S. 4)	Near Salen, Mull. .	Granophyre Hills. 1904.

* *Photographed by* HAROLD PRESTON, *Alverne House, Penzance.* 5/3.

4690	( )	Staffa, from Fingal's Cave.	Columnar basalt. 1905.
4691	( )	Fingal's Cave, Staffa. .	" "
4692	( )	"	" "

Photographed by J. A. SMYTHE, *Armstrong College, Newcastle-on-Tyne.* 1/4.

Regd. No.		
4693	(24 G) Near top of Ben More, Mull.	Pale lavas and dolerites. 1903.
4694	(24 H) Looking S. from Chreagah Mhor, Mull.	1903.
4695	(24 I) Loch na Keal, Mull. .	Glaciated basalt. 1903.

BUTE.—*Photographed by* Professor S. H. REYNOLDS, *University College, Bristol.* 1/4.

Isle of Arran.

4699	(31) Head of Loch Ranza . .	100-foot beach terrace. 1906.
4700	(32) Tormore	Raised shore platform, old sea-cliff and caves. 1906.
4701	(80) Near Corriegills. . .	Old sea-cave in Trias. 1906.
4702	(81) 2 miles S. of Corrie. . .	Old sea-cave in Trias. 1906.
4703	(41) Tormore Shore. . . .	Pitchstone dyke. 1906.
4704	(42) S. of Corriegills Point. .	Weathered surface of pitchstone. 1906.
4705	(43) ,,	Pitchstone intrusion in Trias. 1906.
4706	(44) ,,	,, ,, ,,
4707	(73) $1\frac{1}{2}$ m S. of Corrie. . .	Small granite erratics. 1906.
4708	(74) North of Corrie. .	Large granite erratics. 1906.
4709	(76) Shore S. of Sannox. . .	Two large granite erratics on Trias. 1906.
4710	(77) Just south of Corrie. .	Large granite erratic. 1906.
4711	(78) Near mouth of Corriegills Stream.	Granite boulder. 1906.
4712	(72) Near top of Goatfell. . .	Weathering of granite. 1906.
4713	(69) ,,	,, ,, ,,
4714	(33) Shore 2 m. S of Corrie. .	Dolomitisation along joints in Trias. 1906.
4715	(35) Drumadoon Point. . .	Sill of columnar quartz-porphyry. 1906.
4716	(34) S. of Drumadoon Point. .	Sand dune. 1906.
4717	(37) Drumadoon Point. . .	Quartz-porphyry sill in Trias. 1906.
4718	(39) N.W. of Corriegills Point. .	Platy jointing in felsite. 1906.
4719	(40) Claughlands Point, Lamlash.	Weathering of dolerite. 1906.
4720	(84) Shore N. of Corrie. . .	Weathered block of Old Red Sandstone conglomerate. 1906.
4721	(85) Shore 300 yards N. of Corrie	Pillow structure in Lower Carboniferous lava. 1906.
4722	(45) Largybeg Point. . . .	Dyke, seen from the north. 1906.
4723	(46) ,, ...	Dyke, seen from the south. 1906.
4724	(47) ,, ...	Dyke on shore, seen from above. 1906.
4725	(48) ,, ...	Dyke, seen from below. 1906.
4726	(62) Kildonan.	Basalt dyke. 1906.
4727	(63) ,, ...	Large dyke. 1906.
4728	(64) ,, ...	,, ,,
4729	(50) Tormore.	Dyke forming gully. 1906.
4730	(53) South of Brodick. . .	,, ,,
4731	(51) Between Brodick and Corriegills.	,, ,,
4732	(54) $\frac{1}{3}$ mile S. of Brodick Pier.	Wide gully determined by weathering of dyke. 1906.
4733	(52) 1 mile S. of Brodick Pier. .	Small dyke in Trias. 1906.
4734	(55) N. end of Lamlash Bay. .	Upstanding dyke. 1906.
4735	(56) Shore near Corriegills. .	Small dyke gully in Trias. 1906.
4736	(57) Kildonan.	Basalt dyke in Trias. 1906.
4737	(58) S. of Brodick Pier. . .	Dyke in Trias. 1906.
4738	(60) Largybeg Point. . .	Two small dykes. 1906.

Fifeshire.—*Photographed by* A. S. Reid, *M.A., Trinity College, Glenalmond, N.B.* 1/2.

Regd. No.		
4739	(K.C. 35) Cliff W. of St. Monans	Broken anticline Carboniferous limestones and shales. 1905.
4740	(K.C. 50) Shore below Newark Castle.	Small agglomerate 'neck' in plan on beach. 1905.
4741	(K.C. 49) Shore below Newark Castle.	Small agglomerate 'neck' in plan on beach. 1905.
4742	(K.C. 36) 300 yards E. of Monans Castle.	'White trap' dyke in carbonaceous shale. 1905.
4743	(K.C. 37) Near Ardross Castle, E. of Elie.	Dyke in agglomerate of 'neck.' 1905.
4744	(K.C. 38) Near Ardross Castle, E. of Elie.	Agglomerate in small 'neck.' 1905.
4745	(K.C. 32) Dodhead Quarry, Burntisland.	Dyke passing through carbonaceous shales and forming 'white trap' sill. 1905.
4746	(K.C. 6) Dodhead Quarry, Burntisland.	Dyke passing through carbonaceous shales and forming 'white trap' sill. 1905.
4747	(K.C. 8) Dodhead Quarry, Burntisland	'White trap' sill. 1905.
4748	(K.C. 19) E. end of Binn of Burntisland.	Coarse agglomerate of volcanic 'neck.' 1905.
4749	(K.C. 20) Central part of Binn of Burntisland.	Dyke of columnar basalt in agglomerate of 'neck.' 1905.
4750	(K.C. 25) Binn of Burntisland.	Volcanic 'neck.' 1905.
4751	(K.C. 12) E. end of Kingswood Craig.	Coarse volcanic agglomerate. 1905.
4752	(K.C. 22) E. end of Kingswood Craig.	,, ,, ,, ,,
4753	(K.C. 15) Kingswood Craig, between Kinghorn and Burntisland.	Alternations of basalt, agglomerate, ash, and shale. 1905.
4754	(K.C. 10) Shore E. of Burntisland.	'River terraces.' 1905.
4755	(K.C. 17) Shore between Kinghorn and Kirkcaldy.	Fault in plan on beach. 1905.
4756	(K.C. 16) ½ mile E. of Kinghorn.	Junction of amygdaloidal basalt, with shales and limestones. 1905.
4757	(K.C. 1) Shore by Seafield, Kirkcaldy.	Limestones in Carboniferous Limestone series. 1905.
4758	(K.C. 4) Seafield Castle, S. of Kirkcaldy.	False-bedded sandstone. 1905.

Photographed by Professor S. H. Reynolds, *University College, Bristol.* 1/4.

4759	(A 38) Shore, Kinghorn .	Ejected volcanic block in Carboniferous strata. 1902.

Inverness-shire.—*Photographed by* J. A. Smythe, *Armstrong College, Newcastle-on-Tyne.* 1/4.

4760	(24 J) Cuchullin Hills, Skye .	Outline of hills due to weathering. 1903.
4761	(24 K) Red Hills, from Beinn an Dubhaich, Skye.	Granophyre. 1903.

Photographed by R. F. Gwinnell, *B.Sc., Imperial College of Science and Technology, S.W.* 1/4.

Regd. No.		
4762	(22, 06) Ben Suardal, near Broadford, Skye.	'Grikes' in Durness Limestone (metamorphosed). 1906.
4763	(21, 06) S. of Burial Ground, Kilchrist, near Broadford, Skye.	Dyke of porphyritic basalt. 1906.
4764	(13, 06) Near Loch Ashik, Broadford, Skye.	Roches moutonnées in Torridon Sandstone. 1906.

Photographed by A. T. Metcalfe, *Southwell, Notts.* 1/4.

4689	(G.S. 5) Isle of Rum . . .	Gabbro, &c., Hills. 1904.

Photographed by J. A. Smythe, *Armstrong College, Newcastle-on-Tyne.* 1/4.

4696	(24 D) Laig Bay, Eigg . .	Weathered basalt in Jurassic rocks. 1903.
4697	(24 E) ,, . .	Undercut cliff in Jurassic sandstone. 1903.
4698	(24 F) Top of Sgurr of Eigg .	Tops of columns of pitchstone. 1903.

IRELAND.

*Antrim.—*Photographed by* R. Welch, *M.R.I.A., Lonsdale Street, Belfast.* 1/1.

4765	(562) Slemish	'Volcanic neck.' 1907.
4766	(5110*x*) North Star Dyke. . .	Entrance to old coal-mine. 1907.
4767	(606) Carrickmore Point, Fair Head.	Coal shales in Carboniferous sandstones. 1907.
4768	(608) Carrickmore Point, Fair Head.	Coal shales in Carboniferous sandstones. 1907.
4769	(11108) Carey River, Ballycastle.	Lower Carboniferous sandstones. 1907.
4770	(11107) ,, ,, ,,	,, ,, ,, ,,

Photographed by Miss Mary K. Andrews, 12 *College Gardens, Belfast.* 1/4.

4771	(71) Near Ballintoy. . . .	Raised beach, with caves and stacks of basalt. 1907.
4772	(72) ,, ,, ...	Sea-stacks of basalt. 1907.
4773	(73) ,, ,, ...	,, ,, ,,

*Clare.—*Photographed by* R. Welch, *M.R.I.A., Lonsdale Street, Belfast.* 1/1.

4774	(11129) Black Head . .	Carboniferous Limestone 'pavement.' 1907.
4775	(11151) The Birren, N.W. Clare.	Carboniferous Limestone 'pavement.' 1907.

*Cork.—*Photographed by* R. Welch, *M.R.I.A., Lonsdale Street, Belfast.* 1/1.

4776	(2512) Rostellan Inlet, Cork Harbour.	Partly submerged cromlech. 1907.
4777	(1339) Rostellan Inlet, Cork Harbour.	,, ,, ,, ,,

*DONEGAL.—*Photographed by* R. WELCH, *M.R.I.A., Lonsdale Street, Belfast.* 1/1.

Regd. No.		
4778	(1434) Pollen Bay, Ballyliffan, Inishowen.	'Calcreted' æolian shelly sands. 1908.
4779	(1435) Pollen Bay, Ballyliffan, Inishowen.	" " " " "
4780	(5206) Pollen Bay Dunes. . .	Natural arch in consolidated æolian shelly sands. 1908.
4781	(11166) " " " . . .	Ridge of 'calcreted' sand. 1908.

*DUBLIN.—*Photographed by* R. WELCH, *M.R.I.A., Lonsdale Street, Belfast.* 1/1.

4782	(1669) Broad Bay, Lambay Island.	Cliffs of Old Red Sandstone. 1906.
4783	(1668) North Cliffs, Lambay. .	" " " "

GALWAY.—*Photographed by* A. McI. CLELAND, *Green Road, Knock, Belfast.* 1/2.

4784	(C 11) Mushroom Rocks, near Maycullen.	Eroded Carboniferous Limestone. 1904.
4785	(C 12) Mushroom Rocks, near Maycullen.	" " " "
4786	(C 13) Mushroom Rocks, Ballyquirke Lough.	" " " "
4787	(C 14) Mushroom Rocks, Ballyquirke Lough.	" " " "

ROCK STRUCTURES, &c.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

4788	(6838) Withernsea. . . .	Glaciated boulder. 1905.
4789	(6839) "	" " "

Faunal Succession in the Carboniferous Limestone (Avonian) of the British Isles.—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. (Drawn up by the Secretary.)*

THE following work has been carried out:—

I.—*Faunal Work in connection with Dr. C. A. Matley's Concluding Account of the Rush-Skerries Sequence.*

The results of this investigation were presented to the Geological Society in March of this year and are published in the August number of the 'Quarterly Journal.'

The interrelation of the *Cyathaxonia*- and *Posidonomya*-phases with each other and with the normal Clisiophyllid development of the Upper Avonian is herein discussed, and the possibility of constructing three parallel zonal scales corresponding to these three bathymetric faunas is adumbrated.

In matters of local stratigraphy it is pointed out that the horizon of the Rush Slates and Conglomerates is not yet satisfactorily determined, and it is hoped that further information will be forthcoming as a result of the visit of the British Association to Dublin.

Owing to the large demands made by the Irish work upon my leisure, the publication of an account of the Avonian Sequence in the Gower peninsula, which was carried out in collaboration with Mr. E. E. L. Dixon in the summer of 1905, is again deferred.

II.—*Examination of Material submitted for Identification by other Workers on Lower Carboniferous Rocks.*

The wide application of the zonal sequence determined for the South-Western Province is strikingly exhibited, and the satisfactory correlation of phasal developments is already in view.

III.—Mr. Edward Greenly has collected a fine series of fossils from the Lower Carboniferous Rocks of Anglesey, and has kindly allowed me to draw up an account of the faunal succession from his material. This account will be published shortly in connection with Mr. Greenly's description of the Rock Sequence.

The points of main interest are :—

(*a*) Zonal.—The possibility of subdividing D_2 by mutational species of *Lonsdalia* and *Diphyphyllum.*

(*b*) Stratigraphical.—The age of the basal Carboniferous in Anglesey.

IV.—*Palæontology.*

(1) Notes published in Dr. Matley's Loughshinny paper.

(2) Investigations of the inter-relation of the genera

(a) *Spiriferina* and *Syringothyris.*
(b) *Orthotetes* and *Derbya.*

The results will be published as occasion offers.

(3) Study of the Corals included under *Caninia cylindrica* in my Bristol paper, and of some allied forms recently discovered.

This work is being carried out in collaboration with Mr. R. G. Carruthers, and will be included in his general revision of the Carboniferous Corals.

The grant for this year has been expended on the cutting and photographing of Coral Slices.

For determination of horizon from Corals the satisfactory comparison of new material with the zonal types already accumulated demands—

(1) The cutting of transverse slices from the adult corallum.
(2) The photographing of the slices on an enlarged scale.
(3) The comparison of these photographs with those of the types.

By this method the misleading effects of difference of matrix are almost completely eliminated.

In view of the important investigations now being carried out in widely distant areas by numerous workers in Avonian Rocks, and in the probability that my services may be of use in identification or confirmation, I venture to suggest the continuance of this Committee for yet another year, with a further grant of 10*l.*

In collaboration with Dr. Matley, I hope to complete the account of our work on the Carboniference Sequence at Malahide (Co. Dublin), and to make further progress with the correlation of the Lower Carboniferous Rocks of Fife.

Investigation of the Fauna and Flora of the Trias of the British Isles.—Sixth Report of the Committee, consisting of Professor W. A Herdman (*Chairman*), Mr. J. Lomas (*Secretary*), Professor W. W. Watts, Professor P. F. Kendall, Professor A. C. Seward, Messrs. H. C. Beasley, E. T. Newton, *and* W. A. E. Ussher, *and* Dr. A. Smith Woodward. (*Drawn up by the Secretary.*)

[Plates V. and VI.]

The work of the Committee during the past year has been mainly concerned with an attempt to unravel and classify some of the curious tracks and markings—organic and inorganic—so frequently found associated with footprint-bearing slabs in the Triassic rocks. As many of these are in soft marl and cannot be preserved, advantage has been taken of a large exposure of marl made at Storeton in the latter part of 1907 and the early months of 1908.

Two marl bands which in former excavations were separated by 3 or 4 feet of sandstone have coalesced in the north portion of the quarry now being worked. This probably means that the shores of the lake or pool in which the marls were deposited have been reached.

Under these conditions a new set of phenomena appear, mainly characterised by tracks and burrows of invertebrates, plant remains, and curious markings simulating organic forms.

In the present Report Mr. H. C. Beasley describes some of these forms, and he hopes to complete his investigations in time for next year's Report.

Mr. H. A. Allen also contributes a list of the Triassic fossils in the Warwick Museum, and Mr. A. R. Horwood supplements the Bibliographical Notes contained in the last Report.

Some Rhynchosauroid skulls from Grinshill have lately been acquired by the Manchester Museum which show details of anatomical structure not hitherto observed. These are now under examination, and the Committee hopes to include a full description of them next year.

Report on Tracks of Invertebrates, Casts of Plants, &c., and Markings of uncertain origin from the Lower Keuper. Part I. By H. C. Beasley.

The sandstones and marls of the Lower Keuper frequently show a great variety of superficial markings which, whilst bearing no resemblance to the footprints of vertebrates, may give us some information regarding the invertebrate fauna and the flora as well as some indication of their physical surroundings.

Besides these there are markings due to movements in the rock itself during and subsequent to its consolidation.

The first requirement is the division of the markings due to organisms from those due to purely physical causes. Here we are met by two chief difficulties. We have to deal with natural casts giving the outward form only and no trace of internal structure, and secondly we find that purely physical causes give rise to forms closely resembling those attributable to organisms.

It is evident that a study of the tracks of recent animals is a most essential preliminary. Here the work of Professors Nathorst and Hughes will be of great assistance; both these authors give descriptions and carefully drawn and photographed figures of actual tracks of known animals.[1]

It will be found, however, that the record of a few score of species will cover but a small part of the variety of tracks, and it will readily be seen that the varying circumstances under which the tracks were produced must greatly modify their form.

In the meantime a record of some of the fossil tracks and other markings found in the Trias, more or less systematically arranged, may be of use.

The forms that are readily identified may be divided into tracks of animals and casts of plants, and markings evidently inorganic which may be classed together as such and subdivided according to their resemblance to forms which we may now observe in course of production, such as stream courses, rain pittings, ripples, &c.

But between these principal groups we shall have to deal with a number of forms of very doubtful origin, simulating organic forms or markings possibly attributable to organisms, also with a number of forms whose origin is very uncertain, but which do not simulate any known organic forms. We shall then have

Organic.—	Tracks of invertebrates.
,,	Casts of plants.
Of Doubtful Origin.—	Markings simulating plant forms.
,, ,,	,, ,, animal ,,
,, ,,	Parallel or concentric lines, fillets or ridges.
,, ,,	Lines, &c., neither parallel nor concentric.
Inorganic.—	Rain pittings, and similar forms.
,,	Ripple marks.
,,	Wrinkles and other irregular markings possibly due to movements in the rock itself.
,,	Pseudomorphs.

Markings of Organic Origin.

Tracks of Invertebrates.—The most common of these are sinuous markings in relief about 2 mm. or more in width, roughly semicircular in each section, with a slight groove on each side (indicating a ridge in the original track). The windings are frequent and intricate. They are often referred to as 'annelide tracks,' but the tracks of recent worms are comparatively free from short turns, and these bear more resemblance to the tracks of small Gasteropods, so frequent between tide-marks on a muddy

[1] 'On some Tracks of Invertebrates, &c., and their Palæontological Bearing,' by A. G. Nathorst, *Kon. Svenzka Vet. Akad. Handlingar*, Band 18, No. 7, December 30, 1880.

'On some Tracks of Terrestrial and Freshwater Animals by Professor T. McK. Hughes, *Quart. Journ. Geol. Soc.*, vol. xl. p. 178.

shore. The beaded markings that are often seen in Gasteropod tracks would hardly be visible on these small tracks, and would certainly not be preserved in the sandstone cast.[1] Small cylindrical projections are often found in the underside of the beds of sandstone, which may possibly be casts of worm-burrows, but no connection has been found between them and the tracks above described.

In the underlying clay there are sometimes found horizontal lines of small cylinders of sandstone about 3 mm. thick and of varying length, mostly from 2 to 3 cm., and looking like strings of elongated beads. These appear to be casts of horizontal burrows. As they are not attached in any way to the overlying bed of sandstone they are usually lost as the clay wears away. No connection has been seen between these and the vertical projections mentioned above, nor with the horizontal burrows sometimes seen in the overlying bed of sandstone.

On the upper surface of the sandstone in two instances (one at Storeton, another at Frodsham) are small horizontal tunnels, the roof forming a ridge on the surface, but it is often broken in, leaving the lower part of the tunnel as a groove. In accounting for some similar markings in a bed of fine-grained sandstone in the Carboniferous Limestone, Mr. Albany Hancock has described the superficial burrows of a small amphipod,[2] which was identified as *Kröyera arenaria.* Both the fossil and the recent burrows bear a great resemblance to those in our Keuper Sandstone.

We occasionally find on the upper surface of the beds of sandstone small heaps of rod-like bodies each about 5 mm. broad and from 2 to 10 cm. long, which look like worm castings; they are, however, nearly straight, and not bent and twisted like the castings of both land and marine worms as usually seen; but it should be noted that where such castings are ejected under shallow water they are more or less straight, and do not form the convolutions usually found in worm castings.

No connection has been clearly traced between the castings and any burrows.

We have no help from fossil remains in this investigation. The remains of the worms themselves we could hardly expect to be preserved; and, on the other hand, the absence of any remains of the hard parts of amphipoda or any other crustaceans in the Keuper sandstones is, we know, no proof of their non-existence.

At present no opportunity of comparing the track of the only invertebrate whose remains are present—Estheria—with the fossil markings has presented itself.

Tracks apparently formed by the appendages of some invertebrate have been found on the upper surface of a bed of yellowish, soft, fine-grained sandstone at Storeton. The track consists of two irregular but approximately parallel rows, about 1 cm. apart, of small crescentic transverse pits alternating with slight ridges apparently connected with the convex margin of the pits, as if caused by the backward pressure of a foot. The breadth across the crescents varies from 1·5 to 2 mm. The

[1] Nathorst, *op. cit.* plate vii. fig. 1, 'Tracks of *Montacuta bidentata.*' For Fossil Track see *Trias Committee's Report*, 1904, plate viii.

[2] 'Remarks on Certain Vermiform Fossils found in the Mountain Limestone Districts of the North of England,' by Albany Hancock. *Ann. and Mag. Nat. Hist.* vol. ii. 3rd Series, 1858, p. 443.

distance from the convex border of one pit to that of the next varies greatly, but is generally somewhere near 2 mm. It will be readily understood that, owing to the comparative coarseness of the material and the slightness of the impressions, any measurement of such small objects can only be approximate—several series of tracks are 12 cm. or more in length, and often several series are found within a few inches of each other. There is no doubt that they are actual prints (not casts). One specimen is in the Natural History Museum (T. 235) and several others are in private collections, but they all came from the same place, and were found within a short time of each other (Plate V., fig. 1).

Though very like the tracks of small shore-crabs, they more nearly resemble the tracks of the Chætopod *Nychia cirrosa*, described and figured by Nathorst,[1] which, however, does not show the crescentic form so clearly.

The rarity of remains of plants in the Lower Keuper is well known, and the few there are are but fragmentary. The absence of carbonaceous matter, and their being preserved only as casts, entirely precludes any knowledge of their internal structure. There can, however, be little doubt that a series of casts resembling those of fragments of Equisetiform plants really represent the remains of a Triassic flora. They may be described as much flattened, cylindrical stems, generally about 1 or 2 cm. in width, crossed at intervals in many specimens by serrated joints or nodes, and sometimes associated with narrow leaves (Plate V., fig. 2). One specimen from Storeton in the Liverpool Museum has its upper termination clearly preserved. It is figured by Mr. G. H. Morton in his 'Geology of Liverpool,' and named by him *Equisetum keuperina*. The late Mr. F. M. Webb examined it for Mr. Morton and described it as 'the upper portion of an Equisetum, but without any remains of fructification; the stem is simple, sulcate grooves $1\frac{3}{4}$ lines in breadth. The teeth of the sheaths are triangular, measuring when perfect $1\frac{1}{4}$ lines in length.[2] The other fragments from Storeton and elsewhere so entirely agree with this that it is fairly safe to consider them as casts of plants. A large group of such fragmentary remains has quite recently been found at Storeton, and is now in the Liverpool Museum.

Some markings on a slab at Warwick,[3] if plants at all, may possibly represent plants of the same character. The flattened stem is two or three times the width of those from Cheshire. There are no nodes on the lengths preserved, the longitudinal ribs are separated by a flat surface several times their width. The whole stem narrows slightly towards one end, which has the appearance of being crushed and frayed, all the ribs being continued as separate rods and bending in different directions. The sides of the main stem are fringed with markings resembling leaflets. There are other similar markings on the same slab. There are no definite footprints on this slab. There is another very similar marking on a slab with footprints, probably from the Upper Keuper Sandstone at Shrewley, also in the Warwick Museum.

A much more perfect example of what appears to represent something very similar is on a slab in the Natural History Museum (R. 730), from

[1] *Op. cit.* plate ix. fig. 2.

[2] Morton's *Geology of Liverpool*, 2nd edition, p. 115, plate xii.

[3] 'Slab of Keuper Sandstone with impressions of plants upon it from Coten End Quarry, 1872,' Warwick Museum.

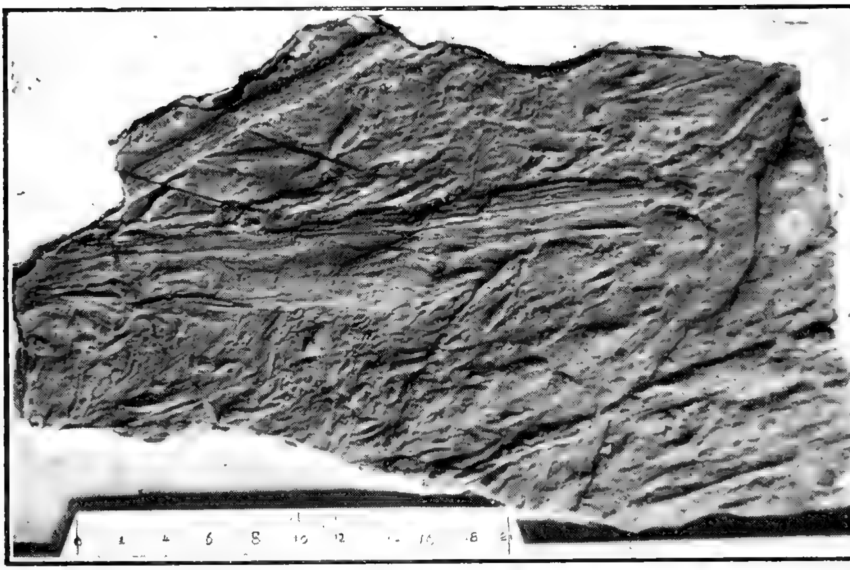


FIG. 1.

FIG. 2.

Illustrating the Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

Storeton;[1] it is accompanied on one side by two Cheirotheroid prints, and numerous other prints are on the stone (the whole in relief). It is about 90 cm. long by 4 to 5 cm. broad; the ribs are close together, and in the more perfect portion of the fossil are each covered by a row of scutes or scales. The other end of the fossil seems rather narrower and to have been crushed and the rods separated as in the Warwick fossil.

It has been suggested that this represents the tail of some large reptile; the relative position of the footprints does not favour this, and it would seem unwise to give any opinion here as to the nature of this or the Warwick fossil.

Markings of uncertain origin simulating Organic Forms.

Plant Forms.—The commonest of these are in the form of branching stems bordered by small leaflets and often marked with longitudinal grooves and ridges.

The whole of these features are seldom combined on one specimen, but they are so associated that there is little doubt of their being all due to one cause.

A good example of a branching form fringed with leaflets is on a slab, No. 7, in the Bootle Museum (Plate VI., fig. 1). Another block of stone in an old quarry at Runcorn has what resembles a root-stem, about 6 inches broad and several feet in length, fringed along one border with small rootlets at about right angles to its axis.

Both these are in relief, and a little examination shows the probability of their being natural casts of stream courses of shallow water, such as may be seen in formation wherever a broad shallow sheet of water is passing over a very gently sloping surface of fine material. The formation of the grooves and ridges has also been noticed and of markings similar to leaf scars; in the latter case, however, the scars were of organic origin, being due to some animal, probably a crustacean, taking advantage of the rather deeper water to follow the retreating tide and with its appendages making regular markings along the narrow channel. In the natural cast formed on the under surface of a succeeding deposit the stream course would be represented by a ridge with what might be easily mistaken for scars or scales upon it.

The pseudo-leaflets are the beginning of channels of small tributary streamlets, and a combination of ridges and flutings on the main course with the border of tributary streamlets has been observed on more than one occasion.

The instances given have been drawn from the seashore between tide-marks of which we know nothing in the Trias, but exactly the same action would take place where a shallow current of fresh water flowed over a similar surface; in fact it has been seen to take place under fresh-water conditions such as are perfectly compatible with what we know of the Lower Keuper.

Other branching forms are free from leaflets or ridges, but have a roughened surface and the semblance of knots and stumps of broken-off branches, simulating portions of our recent trees. A careful examination shows that they are not really plant remains, although their origin is very uncertain.

[1] For figure of this, see Morton, *Geology of Country around Liverpool*, Appendix, p. 300, Plate XXII.

The supposed fucoids of which lithographs were published in Liverpool about 1837–1841[1] were very probably casts of stream courses. It is unfortunate that the originals are not to be found, unless the branching form in the Bootle Museum be a portion of one, neither is the original of *Dictyophyllum crassinervium* figured in Murchison's 'Silurian System'[2] accessible.

A very singular marking, bearing a distant resemblance to a mass of coarse fibre, has been noticed in relief on the underside of several slabs from Storeton.[3] It consists of a patch of fine sharp ridges, or rugæ, curved or waved, seldom rectilinear, tending to lie in one direction but occasionally crossed by others.

Such markings occur most frequently in irregular patches of a few inches area, but in some cases they take the form of groups of truncated oval masses in low relief. The ovals vary slightly in size in each group, but they measure about 10 cm. by 6 cm. and rise in the centre about 1 cm. above the general surface of the stone. The ridges are roughly triangular in section and from 1 mm. to 3 mm. in width. They are arranged with a certain symmetry on each side the long axis of the oval, the broadest part of each ridge is nearest the round end of the oval, of which the margin is clearly defined; the finer extremities of the ridges seem to diverge somewhat at the truncated end, and there is no defined margin. The ridges are rather irregularly disposed, being in some cases in actual contact and in others 50 mm. apart. The ovals themselves are grouped irregularly, generally more or less overlapping one another. One group is large enough nearly to cover a surface 50 cm. by 35 cm. (Plate VI., fig. 2).

In another instance there is an irregular mass covering several square feet of surface with no defined arrangement of ridges and no definite margin. Adjoining it there is a single oval similar to those described, but rather larger. On the same slab are sundry other smaller patches and a great variety of footprints.

It is at present impossible to judge whether these markings be of animal, vegetable, or inorganic origin.

Description of Plates.

PLATE V, FIG. 1.—Invertebrate Tracks from North Quarry, Storeton. One-third natural size. (In J. Lomas's Collection.)

PLATE V, FIG. 2.—Natural casts of Fragments of Plants from Flaybrick, Birkenhead; in relief. (In H. C. Beasley's Collection.)

PLATE VI, FIG. 1.—Natural casts of Stream Courses simulating plant forms, probably from Storeton. (No. 7 in Bootle Museum Collection.) By kind permission of the Bootle Museum Authorities.

PLATE VI, FIG. 2.—Group of oval patches of Matted Rugæ from Storeton; in low relief. (In H. C. Beasley's Collection.)

List of British Triassic Fossils in the Warwick Museum. *By* H. A. ALLEN.

The Warwick Museum possesses the greater part of the Labyrinthodonts found in this country. The specimens were obtained from the neighbourhood of Warwick, and were presented by Dr. Lloyd, Mr.

[1] See *Proc. Liv. Geol. Soc.*, vol. ix. p. 286, for description of lithographs.
[2] Part I., p. 43. Also Lindley and Hutton, *Fossil Flora*, vol. iii. plate 201.
[3] See 1904 *Report*, Plate VIII., for two small patches.

FIG. 1.

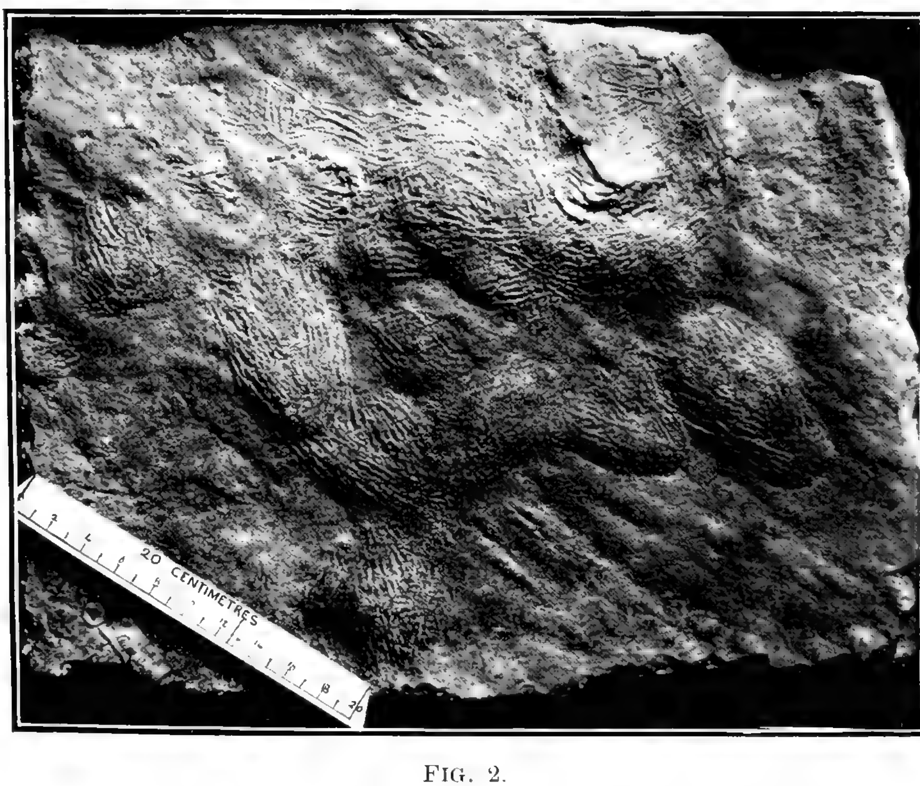


FIG. 2.

Illustrating the Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

J. W. Kirshaw, the Rev. P. B. Brodie, and others. Several of these fragmentary remains have been described by Owen, Huxley, and Dr. Miall in the various memoirs mentioned below. In addition to the specimens included in the following list the Museum contains a large number of undetermined fragments of Triassic amphibia and reptilia. The originals of the mandibles described by Owen as *Labyrinthodon jaegeri*, from Guy's Cliff, appear to have been lost, or were destroyed in making the casts from which the figures were drawn.

Dr. Fr. von Huene, in the course of an examination of the vertebrates of the district, found that the rocks near Kenilworth contain Triassic reptiles; consequently, it is considered advisable to include a few specimens from strata which were first regarded as of Bunter and then of Permian age, in case a revision of the map prove the Trias to extend over a portion of the area now mapped as Permian. Specimens from the Rhætic are not included in this list. The footprints contained in the Museum were recorded by Mr. Beasley in the Reports for the years 1905 and 1906.

PLANTÆ.

Name.	Formation.	Locality.
Breea eulassoides, *Caulerpites oblonga*, *C. triangularis*. These specimens are mentioned, without description, in 'The Geol. Warwickshire Coalfield' ('Mem. Geol. Surv.'), 1859, p. 32.	Permian ?	Meriden.
Dadoxylon ? and a large series of fragments of tree-trunks.	Permian ?	Allesley.
Plant remains (indeterminable)	Keuper	Shrewley and Rowington.

MOLLUSCA.

Name.	Formation.	Locality.
Impressions of mollusca referred to *Nucula*, *Pholadomya*, and *Thracia*.	Keuper	Shrewley.

CRUSTACEA.

Name.	Formation.	Locality.
Estheria minuta (Alberti)	Keuper	Shrewley.

PISCES.

Name.	Formation.	Locality.
Acrodus ? keuperinus (Murch. and Str.), teeth and dorsal fin-spines.	Keuper	Shrewley and Rowington.
Dictyopyge superstes (Eg.), fragment of fish.		
Semi-onotus brodiei Newt., imperfect fish.		

AMPHIBIA.

Name.	Formation.	Locality.
Dasyceps bucklandi (Lloyd). Type, skull. Described as *Labyrinthodon bucklandi* by T. Lloyd, 'Rep. Brit. Assoc. for 1849,' p. 56. Figured as *Dasyceps* by T. H. Huxley, 'Warwickshire Coalfield' ('Mem. Geol. Surv.'), 1859, pp. 52–56.	Permian ?	Kenilworth.
Diadetognathus varvicensis, Miall. Type. Portions of mandibles and teeth described by Dr. L. C. Miall, 'Quart. Journ. Geol. Soc.,' vol. xxx., 1874, Pl. XXVII., f. 3*a*, *b*, p. 425; Pl. XXVIII., figs. 1, 2, pp. 424 and 427. Cranial bones, figured by R. Owen, 'Trans. Geol. Soc.,' Ser. 2, vol. vi., 1842, Pl. XLVI., figs. 6, 7, p. 538, as *Labyrinthodon pachygnathus*, are with some hesitation referred to this species.	Keuper	Coten End, Warwick.

AMPHIBIA—continued.

Name.	Formation.	Locality
Labyrinthodon leptognathus, Owen. Type. Fragments of upper jaw and mandible described by R. Owen, 'Trans. Geol. Soc.,' Ser. 2, vol. vi., 1842, Pl. XLIII., figs. 1–3, p. 516; Pl. XLIV., figs. 7–9, p. 521.	Keuper . .	Coten End, Warwick.
Labyrinthodon, undetermined bone of. Figured by R. Owen, *loc. cit.*, Pl. XLIII., figs. 12, 13.	Lower Keuper	Coten End, Warwick.
Mastodonsaurus giganteus (Jaeger). Fragment of jaw with teeth, figured by R. Owen, 'Trans. Geol. Soc.,' Ser. 2, vol. vi., Pl. XLIV., figs. 4–6, p. 537. Thoracic plate described by Dr. L. C. Miall, 'Quart. Journ. Geol. Soc.,' vol. xxx., 1874, f. 2, pp. 429, 430; also fragments of thoracic plates.	Lower Keuper	Warwick.
Mastodonsaurus pachygnathus (Owen) Type. Portions of upper and lower jaws described as *Labyrinthodon* by R. Owen, 'Trans. Geol. Soc.,' Ser. 2, vol. vi., 1842, Pl. XLIII., figs. 4–12, p. 526. Pl. XLIV., figs. 1–3, p. 526, refigured by Dr. L. C. Miall, 'Quart. Journ. Geol. Soc.,' vol. xxx., 1874, Pl. XXVI., figs. 4*a*, *b*. Bone from the orbital region described by Dr. L. C. Miall, *loc. cit.*, Pl. XXVI., fig. 1*a*, p. 418; portions of mandibles, Pl. XXVI., f. 3*a*, *b*, p. 422; portions of skull, Pl. XXVII. figs. 1*a*, *b*, 2, pp. 419, 421.	Lower Keuper	Warwick.
Mastodonsaurus, sp. Portion of skull described by Dr. L. C. Miall, 'Quart. Journ. Geol. Soc.,' vol. xxx., 1874, Pl. XXVI., f. 2*a–c*, p. 421.	Keuper . .	Warwick.
Mastodonsaurus? Portion of skull described by Dr. L. C. Miall, 'Quart. Journ. Geol. Soc.,' vol. xxx., 1874, Pl. XXVII., f. 4*a*, *b*, p. 433.	Keuper . .	Blakedown Hill, Warwick.

REPTILIA.

Name.	Formation.	Locality
Cladyodon lloydi, Owen. Tooth, figured as *Megalosaurus?* by Murchison and Strickland, 'Trans. Geol. Soc.,' Ser. 2, vol. v., 1840, Pl. XXVIII., f. 6, 8, p. 344.	Lower Keuper	Coten End, Warwick.
Hyperodapedon gordoni, Huxley. Palato-maxillary bones.	Lower Keuper	Coten End, Warwick.
Rhombopholis scutulata (Owen). Portions of skeleton and a dermal scute, figured by R. Owen, 'Trans. Geol. Soc.,' Ser. 2, vol. vi., Pl. XLVI., figs. 1–5, as *Labyrinthodon* (*Anisopus*) *scutulatus*.	Lower Keuper	Warwick.
Thecodontosaurus antiquus, Morris. Vertebræ figured as *Labyrinthodon pachygnathus* by R. Owen, 'Trans. Geol. Soc.,' Ser. 2, vol. vi., 1842, Pl. XLV., figs. 1–8, p. 532. Three sacral vertebræ figured by T. H. Huxley, 'Quart. Journ. Geol. Soc.,' vol. xxvi., 1869, Pl. III., f. 9, p. 46.	Lower Keuper	Warwick.
Thecodontosaurus cylindrodon (Riley and Stutch.). Figured by R. Owen, 'Trans. Geol. Soc.,' Ser. 2, vol. v., Pl. XXVIII., f. 9, p. 343.	Keuper . .	Leamington.

REPTILIA—continued.

Name.	Formation.	Locality.
Thecodontosaurus sp. A dorsal vertebra described by T. H. Huxley, *loc. cit.*, p. 47; left ischium; right ilium, figured by R. Owen, *loc. cit.*, Pl. XLV., figs. 16, 17, p. 533.	Lower Keuper	Coten End, Warwick.
Genus? Episternal bone, figured by R. Owen, 'Trans. Geol. Soc,' Ser. 2, vol. vi., 1842, Pl. XLV., figs. 9, 10, p. 524; coprolite, Pl. XLV., f. 19; femur, Pl. XLV., f. 18, p. 535; humerus, Pl. XLV., figs. 11-15, p. 533.	Lower Keuper	Warwick.
Tooth of a saurian, figured by Murchison and Strickland, 'Trans. Geol. Soc.,' Ser. 2, vol. v., 1840, Pl. XXVIII., f. 8, p. 344.	Keuper . .	Coten End, Warwick.
'Bone of a fish,' figured by Murchison and Strickland, 'Trans. Geol. Soc.,' Ser. 2, vol. v., 1840, Pl. XXVIII., f. 5, p. 348.	Permian? .	¾ mile north-west of Coventry.

Bibliographical Notes on the Flora and Fauna of the Trias, 1826–76. *By* A. R. Horwood, *Leicester Corporation Museum.*

In the Report for 1907 some notes were given upon the flora and fauna of some of the Midland counties. The following summary is supplementary to that account, and includes recorded plant or animal remains from different areas cited in the works enumerated in the Bibliography appended, from 1826–76. Later records are mainly incorporated in previous Reports, and the same remark applies to the remaining works recording Triassic sections, fossils, &c. These will be found chiefly as footnotes to Reports I.–V., 1903–07.

Notes Additional on the Flora and Fauna of the Trias in Leicestershire, Notts, Warwickshire, Worcestershire, Staffordshire, Cheshire, Lancashire, Dumfries, Elgin, and Somersetshire.

(Numbers in parentheses in last column refer to number of work in Bibliography on pp. 281 and 282.)

Genera and Species	Formation	Locality	Reference
PLANTÆ.			
THALLOPHYTA.			
Fucoidal impressions . .	Upper Keuper sandstone	Finwood Green, Warwickshire	(23) p. 42.
Fucoids	Keuper . . .	Shrewley, Warwickshire	(30) p. 121.
PTERIDOPHYTA.			
Equisetales.			
Equisetites arenaceus, Brongn. .	Upper Keuper sandstone	Pendock, Worcestershire	(20) p. 451.
(?) ,, sp. (under *Calamites*)	Keuper . . .	Shrewley, Warwickshire	(31) p. 97.
,, ,, ,,	Upper Keuper sandstone	Rowington, Warwickshire	(21) p. 375.
GYMNOSPERMÆ.			
Coniferæ.			
Voltzia sp.	Keuper . . .	Shrewley, Warwickshire	(31) p. 97.
,, ...	Upper Keuper sandstone	Rowington, Warwickshire	(21) p. 375.

Notes, Additional—continued.

Genera and Species	Formation	Locality	Reference
PLANTÆ—*cont.*			
INCERTÆ SEDIS.			
'Calix of unknown plant' .	Keuper . . .	Shrewley, Warwickshire	(31) p. 97.
'Calyces of some flowering plant'	Lower Keuper sandstone	Rowington, Warwickshire	(22) p. 166.
'Cast of the flower of a plant' .	Keuper . . .	Western Point, Cheshire	(31) p. 97.
'Fruit of an unknown plant' .	,, . . .	Leicester . . .	(31) p. 97.
'Fruits of plants (?)' . .	,, . . .	Rowington, Shrewley, Warwickshire	(30) p. 121 and (21) p. 375.
'Plants (various)' . .	,, . . .	Rowington, Warwickshire	(22) p. 166.
,, ,, ...	,, . . .	Shrewley, Warwickshire	(31) p. 97.
'Plants'	Upper Keuper sandstone	North Curry, Somersetshire	(26) p. 484.
[*Dictyophyllum crassinervium*, L. and H.]	'New Red sandstone'	Clarence Dock, Liverpool	(3) pp. 135–7, Pl. CCI.
,, ,,	,, ,, ,,	Liverpool . . .	(13) p. 193.
,, ,,	Trias	,, ...	(19) p. 7.
[*Echinostachys oblonga*, Brongn.]	,, . . .	Bromsgrove, Worcestershire	(13) p. 193; (19) p. 8.
,, ,,	Lower Keuper sandstone	Ombersley, Worcestershire	(30) p. 70.
,, ,,	Keuper . . .	Shrewley . . .	(31) p. 97.
[*Walchia hypnoides*, Brongn.] .	Trias	Warwickshire . .	(19) p. 24.
,, ,,	Keuper . . .	Shrewley . . .	(31) p. 97.
INVERTEBRATA.			
ANNELIDA OR CRUSTACEA.			
'Annelide holes and tracks' .	Lower Keuper sandstone	Brewood, Penkridge, Worcestershire	(30) p. 71.
'Worm-tracks'	,, ,, ,,	Weston Cliff, Notts. .	(30) p. 91.
CRUSTACEA.			
Estheria minuta (Alberti) .	Lower Keuper sandstone	Burge Hill, Worcestershire	(30) p. 90.
,, ,, ,, . .	Keuper . . .	Shelsey, Worcestershire	(28) pp. 57–8.
,, ,, ,, . .	Upper Keuper sandstone	Rowington, Finwood Green, Warwickshire	(23) p. 42.
,, ,, ,, . .	,, ,, ,,	Tunnel, Malvern Wells	(27) p. 153.
,, ,, ,, . .	,, ,, ,,	Ruihston, Somersetshire	(29) p. 468.
,, ,, ,, . .	,, ,, ,,	North Curry . .	*Ibid.*
,, ,, ,, . .	Keuper . . .	Stoke St. Mary . .	(33) p. 374.
MOLLUSCA.			
'Cast of bivalve shell' . .	,, ...	Rowington & Shrewley, Warwickshire	(30) p. 121.
VERTEBRATA.			
PISCES.			
'*Hybodus* sp.'	Lower Keuper . .	Burge Hill, Worcestershire	(30) p. 90.
Acrodus keuperinus (M. & S.) .	Upper Keuper sandstone	Ruihston, Somersetshire	(29) p. 468.
,, *minimus*, Ag. . .	Keuper . . .	Shrewley, Warwickshire	(31) p. 97.
,, sp.	Upper Keuper . .	,, ,, .	(30) p. 120 and (21) p. 374.
,, sp.	,, ,, .	Pendock, Worcestershire	(30) p. 120.
,, sp. (fragments of teeth and spines)	Upper Keuper sandstones and marls	Tunnel, Malvern Wells	(25) p. 153.
,, nov. sp. (*fide* Egerton)	Upper Keuper sandstone	Pendock, Worcestershire	(20) pp. 450-1.
Dictyopyge superstes (Eg.) . .	Keuper . . .	Shrewley, Warwickshire	(30) pp. 5, 121, and (31) p. 97.

Notes, Additional—continued.

Genera and Species	Formation	Locality	Reference
VERTEBRATA—*cont.*			
INCERTÆ SEDIS.			
'Serrated teeth of *Belodon*' .	Upper Keuper sandstone	Ruibston, Somersetshire	(29) p. 468.
'*Leptodus* (?) sp.'	" " "	Shrewley, Warwickshire	(30) p. 120.
'*Lophodus* palatal tooth, spine'	Keuper . . .	" " .	(31) p. 97.
'Jaw of fish'	Trias	Coventry Warwickshire	(4) Pl. XXVIII. fig. 5; (19) p. 346.
'Fish-teeth'	Upper Keuper sandstone	Rowington " .	(21) p. 374.
"	" " "	Finwood Green, Warwickshire	(23) p. 42.
'Cutting-teeth of a shark: palatal teeth; group in a jaw; very rare'	Keuper . . .	Rowington, Shrewley, Warwickshire	(30) p. 121.
'Traces of fish-scales' . .	Upper Keuper sandstone	North Curry, Somersetshire	(29) p. 486.
'Ichthyodorulites' and 'osseous remains'	Upper Keuper sandstone	Pendock, Worcestershire	(20) pp. 450-1.
'Ichthyodorulites of a Cestraciont'	Keuper . . .	Rowington, Shrewley, { Warwickshire	(21) p. 374.
'Shagreen on skin of a Cestraciont'	" . . .		(30) p. 121.
'Large mailed fish'	" . . .	" " .	(30) p. 121.
AMPHIBIA.			
Mastodonsaurus giganteus, Jaeger	Trias	Coten End, Warwickshire	(32) p. 430.
(?) " "	"	Guy's Cliff "	(6) p. 197; (7) p. 188; (9) p. 506, &c.; (19) p. 348.
(?) " "	Lower Keuper sandstone	Warwick . . .	(23) p. 40.
(?) " "	" " "	Cubbington, Warwickshire	(30) p. 88.
(?) " "	" " "	Leamington " .	(30) p. 120.
" *pachygnathus* (Owen)	Trias	Coten End " .	(32) pp. 418, 419, 421, 422; Plates XXVI.-XXVII.
(?) " "	"	" " .	(6) fig. 63 A and 64 B in part; (9) p. 516, &c.; (19) p. 530.
(?) " "	Lower Keuper sandstone	Warwickshire . .	(23) p. 40.
(?) " "	Keuper . . .	Leamington, Warwickshire	(30) p. 6.
(?) " "	Lower Keuper . .	" " .	pp. 120-1.
(?) " "	" " . .	Cubbington . .	"
(?) " "	Keuper . . .	Coten End, Cubbington	(31) p. 97.
" sp.	Trias	Blakedown . .	(32) p. 433.
Labyrinthodon leptognathus (Owen)	Trias	Coten End. . .	(6) p. 207; (9) p. 516 &c.; (19) p. 348.
" "	Lower Keuper sandstone	Warwickshire . .	(23) p. 40.
" " .	Lower Keuper sandstone	{ Warwick, Leamington }	(30) p. 120.
" " .	Keuper . . .	Shrewley, Warwicks.	(31) p. 97.
" " .	" . . .	Coten End "	(32) p. 425.
Diadetognathus varvicensis, Miall.	Trias	Coten End "	(32) p. 425.
Doubtfully Labyrinthodont, or not distinct from the above.			
Cladyodon Lloydii, Owen . .	"	{ Coten End, Leamington	{ (4) Pl. XXVIII. 6; (6) p. 268 (7); (19) p. 348; (30) p. 6; (31) p. 97.
" " (?) .	Lower Keuper . .	Warwick . . .	(30) p. 121.
'*Labyrinthodon conicus*,' Owen .	" " . .	" . . .	(30) p. 121.
" '*scutulatus*' " .	Trias	Leamington . .	(9) p. 538; (19) p. 350.
" " " .	Lower Keuper sandstone	Warwick . . .	(23) p. 40.
" " " .	Keuper . .	{ Leamington, Warwickshire }	(30) p. 6.

Notes, Additional—continued.

Genera and Species	Formation	Locality	Reference
VERTEBRATA—*cont.*			
Amphibia—*cont.*			
'*Labyrinthodon scutulatus*,' Owen	Lower Keuper	Leamington	(30) p. 121; (31) p. 97.
" *ventricosus* "	Trias	Coten End, Warwicks.	(9) p. 505 &c. (19) p. 350.
" "	Lower Keuper sandstone	Warwick	(23) p. 40.
" "	Keuper	Leamington, Warwick	(30) p. 6.
" "	Lower Keuper	Cubbington, Warwick	(30) p. 121.
" "	Keuper	Coten End	(31) p. 97.
" sp.	"	Flaybrick, Cheshire	(30) p. 6.
" "	Lower Keuper sandstone	Daresbury "	(30) p. 6.
" "	" " "	Preston Bagot, Rowington, Warwickshire	(30) p. 90.
" "	" " "	Warwick, Leek Wooton	(30) p. 121.
" "	" " "		
" "	Upper Keuper sandstone	Ruihston, Somersets.	(29) p. 468.
REPTILIA.			
Stagonolepis Robertsoni (Ag.)	Trias	Findrassie	(24) pp. 440–460.
'Imperfect rib-bone'	Upper Keuper sandstone	North Curry, Somersetshire	(26) p. 484.
FOOTPRINTS.			
Rhynchosaurus sp.	Keuper	Flaybrick Hill, Weston Point, Daresbury, Lymm, Cheshire, Liverpool	(30) p. 5.
"	Trias	Warwickshire, Staffordshire, Cheshire	(30) p. 121.
"	Keuper	Rowington, Shrewley	(30) p. 121.
"	"	Warwickshire	(31) p. 97.
Cheirotherium Kaupii (Owen)	Trias	Lymm, Cheshire	(18) p. 37; (19) p. 355.
" sp.	"	Storeton "	(5) pp. 12–14; (19) p. 355.
" sp.	"	Lymm "	(8) p. 56; (19) p. 355.
" sp.	"	Annan, Dumfries.	(14) p. 83; (19) p. 355.
" sp.	Keuper	Flaybrick Hill, Weston Point, Daresbury, Lymm, Liverpool	(30) p. 5.
" sp.	"	Warwickshire, Staffordshire, Cheshire	(30) p. 121.
"	"	Rowington, Shrewley	(30) p. 121.
"	Upper Keuper sandstone	Witley Green, near Preston Bagot	(25) p. 278.
'Steps of Batrachian on ripple-marked Sandstone'	Upper Keuper	Shrewley	(21) p. 374.
Chelonoid and other Footprints from Dumfries.			
Actibatis triassæ, Jard.	Trias	Corncockle Muir	(17) Pl. IX.; (19) p. 355.
Batrichnus lyellii, Jard.	"	Green Mill, near Dumfries	*Ibid.*, Pl. XIII.; (16) p. 95; (19) p. 355.
" *stricklandi*, Hark.	"	Dumfries	(16) p. 95; (19) p. 355
Chelaspodos jardinii, Hark.	"	"	*Ibid.*, p. 92; (19) *Ibid.*
Chelichnus ambiguus, Jard.	"	Corncockle Muir	(17) Pl. VI., XI.; (19) *Ibid.*
" *duncani*, Morris	"	"	(2) p. 194; (7) p. 160; (15) p. 208; (17) Pl. II., III.; (19) p. 355.
" *gigas*, Jard.	"	"	(17) Pl. I.; (19) *Ibid.*
" *obliquus*, Hark.	"	Dumfries	(16) p. 93; (19) *Ibid.*
" *plagiostopus*, Jard.	"	Corncockle Muir	(17) Pl. X.; (19) *Ibid.*
" *plancus*, Hark.	"	Dumfries	(16) p. 92; (19) *Ibid.*
" *titan*, Jard.	"	Corncockle Muir	(17) p. 10; (19) *Ibid.*

Notes, Additional—continued.

Genera and Species	Formation	Locality	Reference
VERTEBRATA—*cont.*			
Footprints—*cont.*			
Chelichnus sp.	Trias	Weston, nr. Runcorn	(15) p. 205; (19) *Ibid.*
Herpetichnus bucklandi, Jard.	„	Corncockle Muir	(15) p. 208; (17) Pl. VII.; (19) *Ibid.*
„ *sauroplesius*, Jard.	„	„	(17) Pl. IV., V.; (19) *Ibid.*
Saurichnus acutus, Hark.	„	Dumfries	(16) p. 94; (19) *Ibid.*
INCERTÆ SEDIS.			
Footprints	„	Weston, nr. Runcorn	(10) p. 65, Pl. V.; (19) *Ibid.*
„	„	„ „	(14) p. 84; (19) *Ibid.*
„	„	Storeton, Cheshire	(11) p. 410; (12) p. 283, fig. 3; (19) *Ibid.*
„	„	Lymm „	(8) p. 56; (19) *Ibid.*
„	„	Shrewley Common, Warwickshire	(4) p. 318, Pl. XXVIII. fig. 1; (19) *Ibid.*
„	Keuper	Shrewley, Guy's Cliff	(30) p. 6.
'Labyrinthodon footprints'	Upper Keuper sandstone	Rowington, Finwood Green	(23) p. 42; (21) p. 375.
„ „	Lower Keuper sandstone	Brewood, Penkridge, Worcestershire	(30) p. 71.
„ „	„ „ „	Longley Hill, Delamere, Cheshire	*Ibid.*, p. 79.
„ „	„ „ „	Quarry at Eaton, Cheshire	*Ibid.*, p. 80, fig. 41.
„ „	„ „ „	Weston Quarries, Cheshire	*Ibid.*, p. 85.
„ „	„ „ „	Lymm, Cheshire	*Ibid.*, p. 86, section.

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[1] This does not apply to works quoted in which records of fossil plants or animals occur, but have so far not been detailed.

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Composition and Origin of the Crystalline Rocks of Anglesey.—Third Report of the Committee, consisting of Mr. A. HARKER (*Chairman*), Mr. E. GREENLY (*Secretary*), Mr. J. LOMAS, Dr. C. A. MATLEY, *and* Professor K. J. P. ORTON.

THE analyses contained in this Report, like those of last year, have been drawn up by Mr. John Owen Hughes, B.Sc., who contributes a chemical note upon them. They have all been executed by himself.

In almost every case they have been chosen for the purpose of throwing light on difficult questions of the origin of highly altered rocks, and a discussion of them would lead far into complicated metamorphic questions, to which justice could not be done apart from microscopic structures and detailed field relations. In this place, therefore, only the nature of the rock and the bearings of the analysis will be given, sufficiently to make its objects clear.

Two more rocks belonging to the zone of hornfels in Central Anglesey have been analysed. When one more, a very important one that is now in progress, is completed, that particular line of investigation will be at an end for the present, a typical selection having been examined.

The remaining rocks belong to other groups, and have been selected partly to aid field-work actually in progress at the time, partly because the specimens had long ago been collected for analytical purposes, and it seemed advisable to get them examined and out of hand.

The next line of investigation it is proposed to take up systematically is that of the composition of the pillowy diabase and jasper group, with the metamorphic rocks associated with them, a question of great importance upon which some chemical work has been done already.

The numbers, as before, are those of the slides in the Secretary's cabinet.

NO. 184A. *Banded Hornfels.*

Ang. 12 *S.E.*; 1,200 *ft. E.N.E. Tai Eiddew.*

	I.	II.
K_2O	4·05	4·04
Na_2O	1·49	1·65

This is a banded hornfels from near Gwalchmai. The object of the analysis is, as in the case of those in last year's report, to aid in deciding whether these rocks are igneous or sedimentary in origin.

NO. 205A. *Garnet Mica Schist.*

Ang. 13 *S.W.*; *N.E. nd Llyn Hendref.*

	I.	II.
K_2O	2·59	2·66
Na_2O	2·44	2·59

Owing to the small amount of material available, only the alkalies could be estimated in the above rock.

This is a garnetiferous mica schist, also from near Gwalchmai, belonging to a zone into which the hornfels appears to pass.

No. 374A. *Greenish Mica Schist.*

Ang. 16 *N.E.* *Cromlech Farm, Rhoscolyn.*

	I.	II.
K_2O	4·44	4·37
Na_2O	2·46	2·69
SiO_2	53·33	54·01

This is a mica schist from Rhoscolyn, Holyhead Island. It has been selected, although from a different district, for comparison's sake, for there can be no doubt in this case that we are dealing with sedimentary material.

No. 124A. *Muscovite Epidote Schist.*

Ang. 19 *N.W.;* 200 *feet N.W.* '169.' *W. of Hen-durnpike.*

	I.	II.
SiO_2	67·31	67·53
Al_2O_3	17·56	17·45
Fe_2O_3	1·70	1·72
FeO	2·27	2·28
CaO	2·26	2·18
MgO	1·21	1·42
K_2O	2·51	2·54
Na_2O	3·88	3·64
H_2O	1 08	1·04
	99·78	99·80

This is a mica schist from near Penmynydd, in the south-eastern district, and belongs to a series which in one place appear to pass into felsite, in others into sediments. It was selected to complete a group of analyses of which the rest were very kindly made for me some years ago by Mr. Edmund Dickson, F.G.S.

A.P. 38. *Limestone.*

Ang. 19 *N.W.* *Rhydeilian Kiln.*

	I.	II.
Residues insoluble in HCl	3·43	3·97
$Al_2O_3 + Fe_2O_3$	0·40	0·49
MnO	—	—
CaO	29·80	29·69
MgO	20·66	20·15
CO_2	45·96	45·68
	100·24	99·98
∴ percentage $CaCO_3$ =	53·21	53·01
" $MgCO_3$ =	43·18	42·11

A limestone from Rhydeilian, about a mile from No. 124A and in the zone of passage between those rocks and the schists in which sedimentary material can still be recognised.

No. 99A. *Flaky Micaceous Gneiss.*

Ang. 18 *S.E.* *Edge of Wood at wall corner*, 200 *feet N.W.* *Graig Fach.*

	I.	II.
SiO_2	68·05	68·13
Al_2O_3	17·53	17·36
Fe_2O_3	4·84	4·79

A gneiss containing sillimanite from Holland Arms. It occurs at the junction of the mica schists with the hornblende gneisses of that locality.

No. 223A. *Jaspery Phyllite.*

Ang. 18 *N.W.* *In Limestone,* 900 *feet S.W.* (*a little to W.*) *of Hendrebach.*

	I.	II.
SiO_2	63·83	64·02
Al_2O_3	17·49	17·61
Fe_2O_3	6·41	6·67
FeO	0·76	0·70
CaO	0·57	0·62
MgO	5·93	5·82
K_2O	2·38	2·55
Na_2O	0·35	0·33
H_2O	1·49	1·43
	99·21	99·75

A 'jaspery phyllite'—that is, a peculiar red or purple shale closely associated with the jaspers and limestones. This example is from a complex mass, chiefly limestone, near Cerrig Ceinwen. A jasper from the same complex was analysed last year.

No. 425A. *Gabbro.*

Ang. 11 *S.E.* *Lane, foot of High Boss,* 250 *feet W.S.W.* '23·6.'

	I.	II.
SiO_2	46·93	47·11
Al_2O_3	15·91	15·80
Fe_2O_3	0·90	0·98
FeO	3·98	3·93
CaO	11·62	11·23
MgO	14·02	13·96
K_2O	0·21	0·19
Na_2O	1·83	1·98
H_2O (at 110°)	0·17	0·19
H_2O (above 110°)	4·60	4·38
	100·17	99·75

In the above rock H_2O (above 110°) was determined by finding loss of weight on ignition.

A specimen taken from the least deformed portion known to me of the gabbro of Holyhead Island. The serpentine of that complex was analysed many years ago by Mr. F. T. S. Houghton.[1]

No. 429A. *Limestone.*

Ang. 11 *S.E.* 700 *feet S.S.E. of Cerig Moelion.*

	I.		II.
Residues insoluble in HCl	5·32		5·26
$Al_2O_3 + Fe_2O_3$	6·46		6·55
MnO	—		—
CaO	32·94		32·43
MgO	14·41		14·58
CO_2		41·26	
	100·39		100·08
∴ percentage $CaCO_3$ =	58·82		57·91
,, $MgCO_3$ =	30·26		30·47

A peculiar dark, hard limestone that occurs in association with the same serpentine and gabbro. This rock is not the ophicalcite, which I hope later on to deal with.

[1] See Bonney, *Q.J.G.S.*, 1881, p. 46.

No. 422A. *Diorite.*

Ang. 7 *S.W.* *Bodneithior, E. side house.*

	I.	II.
SiO_2	45·21	45·13

Diorite from Bodneithior, Llandyfrydog. It is a less basic portion of one of the Post-Ordovician intrusions, the more basic (and larger) portion of which is the famous hornblende-picrite. For an analysis of that rock see Teall, 'Brit. Petrography,' p. 103.

No. 514A. *Dolerite.*

Ang. 8 *S.W.* *Small dyke N. of Dinas, Traeth Bychan.*

	I.	II.
SiO_2	47·35	47·29

A small basic dyke traversing the Carboniferous limestone on the east coast near Moelfre. The only one known in that district.

Besides these rocks, a suite of six silica percentages have been estimated, each in duplicate, of the very curious altered rocks of Parys Mountain, which have lately been shown to be of Silurian age, and in which the once famous copper mines (still worked by a solution process) are situated. The filtrates are reserved for treatment later on.

On some of the methods Mr. Hughes remarks :—

'The methods employed in the above analyses were described in the report of last year, and no modifications of these, or new methods have been introduced.

'A large number of determinations of alkalies made by the Lawrence Smith method proves that the method, besides being a convenient one, is also very accurate, and great reliance can be placed upon it.

'The steel crusher bought last year continues to give satisfaction, and by its use considerable saving of time is effected in the preliminary process of reducing the rock to powder. This, as well as all other steel apparatus—hammer, mortars, &c.—are kept in a galvanised iron tank, with a tightly fitting cover, containing lime ; in this way rusting is entirely prevented.'

There is still a small balance left, about equal to the amount expended in the course of the past year. The Committee ask to be reappointed, and to retain this balance for use in the coming twelvemonth.

Investigation of the pre-Devonian Rocks of the Mendips and the Bristol Area.—Report of the Committee, consisting of Mr. H. B. Woodward *(Chairman)*, Professor S. H. Reynolds *(Secretary)*, Dr. C. Lloyd Morgan, *and* Rev. H. H. Winwood. *(Drawn up by the Secretary.)*

The pre-Devonian Rocks of the Bristol district include the two inliers of the Eastern Mendips and of Tortworth.

The Eastern Mendip Inlier.

The grant from the British Association, the object of which was to assist the Secretary in studying the Silurian rocks of the Bristol district, was not made till his paper on the 'Silurian Inlier of the Eastern Mendips' had already been published,[1] and the main part of the work on this part of the area had been done. With the aid of the grant, however, several trenches were dug, and a good deal of additional information was obtained both from them and from new exposures made in connection with quarrying operations. Unfortunately, however, it did not prove possible to ascertain the relations of the coarse ashy conglomerate, the most remarkable deposit of the district, to the other rocks. The additional information obtained from various sources since the publication of the paper already referred to is as follows :—

1. *Beacon Farm Neighbourhood.*—Three trenches were dug here ; the first was one-third of a mile N.E. of Beacon Farm, close to the north-eastern border of a plantation. The material here is coarse ashy conglomerate, exactly like that at the Butts on Beacon Hill. Precisely similar material was reached at a depth of 3 feet in a trench dug close to the Roman road and about 300 yards N.E. of the previous trench. These trenches prove that the eastward extension of the coarse ashy conglomerate is much as was previously mapped[2] on evidence derived from material thrown out by moles and rabbits. A third trench at a spot nearly a third of a mile N.W. of Lodge Farm was taken down $7\frac{1}{2}$ feet through loose material full of pieces of trap without anything *in situ* being met with. It is, however, practically certain that the material here is the trap (andesite).

2. *Sunnyhill and Moon's Hill.*—The following section, essentially the same as that in the Sunnyhill quarry, was exposed near the wind pump just S.W. of the quarry :—

	Ft.	In.
4. Compact andesite to top of section		
3. Highly vesicular andesite	3	0
2. Very fine red ashy clay	1	3
1. Fairly coarse tuff	12	0
Thickness of ashy series seen	13	3

The vesicular andesite has vesicles an inch long : the big ones are empty, the little ones filled with chlorite ; the rock is a noteworthy one, as on the whole a vesicular structure is very little met with in the inlier. There are indications of banding in the compact andesite, the banding being parallel to the base of the mass. The line of junction of the andesite and ashy clay is slightly undulating, and is clearly one of deposition, not of faulting or intrusion.

At the time of publication of the previous paper no remains of trilobites had been found in the fine tuff of Sunnyhill, but a single tail of *Phacops* has since been obtained.

Hitherto nothing but andesite has been recorded from the large Moon's Hill quarry, but a band of tuff dipping N.N.E. at about 70° occurs in the little excavation between the two main quarries. It is of a rather coarse-grained type and closely resembles that interbedded in the lower part of the andesite at Sunnyhill.

In a paper already published an analysis of the Moon's Hill rock by Mr. E. M. Lane was quoted. This unfortunately proved unreliable, and

[1] *Q.J.G.S.*, vol. lxiii. 1907, pp. 217–240.
[2] *Ibid.*, vol. lxiii. 1907, p. 220.

the following analysis, made by Mr. J. H. Sturgess in the Chemical Laboratory at University College, Bristol, is intended to replace it :—

SiO_2	61·16
CaO	4·90
Al_2O_3, Fe_2O_3	23·21
MgO	0·62
P_2O_5	0·19
K_2O	2·68
Na_2O	4·84
H_2O	2·11
	99·71

3. *New Line of Rails from Downhead Quarry.*—Since the publication of the previous paper a line of rails has been laid from Downhead quarry, past Walltyning to Long Cross Bottom, and several interesting little sections have been exposed. At a point $\frac{1}{4}$ mile N.E. of Long Cross Bottom there is a cutting in Old Red sandstone and conglomerate dipping S. at 45°. Two hundred yards farther E. a cutting in fine greenish sandy shale yielded the following fossils, which have been identified by Mr. F. R. Cowper Reed :—

Pholidops implicata, Sow.
Lingula Symondsi (?), Salt.
Leptæna rhomboidalis, Wilch.
Spirifer plicatellus var. *radiatus*, Sow.
Atrypa sp.
Crinoid stem joints.
Cœnites labrosus, M. Edw.

A trench opened on the hill slopes a few yards to the N. of this cutting showed similar material, and contained :—

Pholidops implicata, Sow.
Meristella, cf. *furcata*, Sow.
Spirifer plicatellus var. *radiatus*, Sow.
Orthis sp.
Beyrichia sp.
Calymene sp.
Phacops Weaveri, Salt.

In Mr. Reed's opinion these fossils clearly indicate that the rock is of Llandovery age. Judging from the strike, the rocks at this point occur not many feet below the Old Red sandstone, and certainly there would be no room for a development of the Wenlock and Ludlow series between them and the Old Red sandstone. These exposures, therefore, afford confirmation of the view previously arrived at, viz., that the Llandovery rocks of the Eastern Mendips are directly succeeded by the Old Red sandstone. A second exposure of Silurian—in this case a fine-grained grit with shale—occurs near Holland's Copse, about 300 yards to the E. of that just described. No fossils were found here. These three exposures, which are in all probability in the newest Silurian rocks of the district, are noteworthy from the fact that the rocks are normal sediments without any admixture of igneous material, while all the other Silurian rocks throughout the inlier are wholly or partially igneous in origin.

4. *Downhead.*—Hitherto the only evidence of fossiliferous Silurians in this neighbourhood has been afforded by bits thrown out by moles and rabbits. A trench was, however, dug on the hill slope opposite the

Downhead quarry, which at a depth of 15 inches entered fine-grained greenish ash, dipping 12–15° S.E., the dip being such as to indicate that, as at Sunnyhill and probably Tadhill, fossiliferous ash underlies the trap exposed further to the north. Fossils were by no means so common as at Tadhill, the only ones found being

Rhynchonella Davidsoni, M'Coy.
Orthis elegantula, Dalm.
Pterinea sp.
Calymene Blumenbachi, Brong.

The most noteworthy points brought out by the work may be summarised as follows :—

1. Trenching proves that the coarse ashy conglomerate of Beacon Hill extends to a point not far short of ½ mile to the east of the Butts.
2. A band of tuff is found to be interbedded in the Moon's Hill andesite.
3. Sediments free from admixture with igneous matter occur close below the outcrop of the Old Red sandstone, about ¼ mile N.E. of Long Cross Bottom. These, though probably the newest Silurian rocks of the district, contain a fauna of the same general type as elsewhere in the inlier, *i.e.*, probably of Upper Llandovery age.

The Tortworth Inlier.

Far more work has been devoted to the Tortworth inlier than to the Eastern Mendip inlier ; but as the great majority of the facts ascertained are recorded in a paper 'On the Fossiliferous Silurian Rocks of the Southern Half of the Tortworth Inlier,' by Mr. F. R. Cowper Reed and the Secretary, to appear in a forthcoming part of the 'Quarterly Journal of the Geological Society,' they will not be repeated here. It may be mentioned, however, that during the course of the work, which was greatly facilitated by the kindness of the landowners, Lord Fitzhardinge, Sir George Jenkinson, Bart., and especially Lord Ducie, eighteen old quarries or exposures were opened up and about twenty-five trenches were dug.

The most important points with regard to the fossiliferous Silurian rocks which have been ascertained or confirmed by the work are the following :—

1. That the traps form two bands confined (with the possible exception of one small exposure) to the upper Llandovery rocks.
2. That the base of the series is not seen, very little sedimentary material being exposed below the lower trap band, and that the main fossiliferous horizon of the Llandovery, which occurs between the two trap bands, has a thickness of about 500 feet.
3. That the exposures of ashy limestone at Middlemill and Cullimore's quarry, Charfield Green, which had previously been thought to rest respectively on the lower and upper trap bands, are probably on the same horizon and overlie the upper trap band.
4. That the highly fossiliferous calcareous sandstone of Daniel's Wood also overlies the upper trap band, and is of approximately the same age as the ashy limestones of Middlemill and Charfield Green.
5. That a small area of Llandovery rocks occurs in Eastwood Park, and includes an exposure of the same highly fossiliferous calcareous sandstone as occurs in Daniel's Wood.

6. That areas of Wenlock occur in regions formerly mapped as Llandovery to the west of Charfield Green, between Tortworth and Daniel's Wood, and in the neighbourhood of Stone.

7. That, although certain fossils of Ludlow type have been met with near Horseshoe Farm and to the south of Little Daniel's Wood, only a very thin, imperfect, and non-typical development of these rocks exists; and this fact, taken in connection with the remarkable attenuation of the Old Red sandstone, renders it probable that the district was upheaved and subjected to erosion in late Silurian and early Old Red sandstone times.

The paper by Mr. F. R. Cowper Reed and the Secretary describes only the fossiliferous Silurian rocks, the igneous rocks having been already described in a paper by Professor Lloyd Morgan and the Secretary, published in 1901;[1] but in the course of the work a certain amount of additional information was obtained with regard to the 'trap' rocks, which may be given here. In the first place a considerable number of new exposures has been obtained, especially between Middlemill and Woodford. The great majority are not inconsistent with the view maintained by Professor C. Lloyd Morgan and the Secretary in the paper above referred to, that both the upper and lower trap bands are regularly interbedded with the sedimentary rocks. The forking of the trap to the west of Woodford Green does not present any difficulty to the contemporaneous hypothesis, being explicable on the view that the trap is folded into a syncline, and the isolated patch at Woodford Farm may be regarded as brought in by a roll in the strata. There is, however, one small patch of trap which it has been found very difficult to connect with such a scheme: it lies to the west of the northern end of Daniel's Wood, in an area which, as far as the very limited amount of evidence available goes, is Wenlock. We are inclined to think that this reopens the question as to whether or not some of the trap may be intrusive, and it must be admitted that there are certain facts, such as the strong divergence of the two trap bands to the west of Damery and the enclosure in parts of the Damery trap of much sedimentary matter, which are best explained on the view that the lower trap band is intrusive. The field evidence is, however, scarcely sufficient to warrant at present a definite opinion. The chief points brought out by examination of rock sections cut from new exposures are:—

1. The prevalence of andesitic rocks containing bastite pseudomorphs after enstatite. These have already been recorded from Charfield Green, Woodford Green, and Daniel's Wood, and we have now met with them to the W. of the Fox Inn at Woodford and in trenches to the S.E. of Crockley's Farm, Tortworth.

2. The frequent occurrence of quartz xenocrysts with corroded borders. These were recorded in the paper previously referred to from Warner's Court, Charfield Green, Daniel's Wood, Woodford Green, and Middlemill; but, except perhaps at Daniel's Wood, they are best seen in the old quarry W. of the Fox Inn at Woodford, an exposure not recorded in the previous paper. All these localities probably lie on the upper trap band.

3. It is perhaps worth noting that the pyroxene andesite exposed in

[1] *Q.J.G.S.*, vol. lviii. 1901, pp. 267–284.

the trench S.E. of Crockley's Farm shows little patches of a colourless mineral, apparently chalcedony, sometimes scattered through the body of the rock, sometimes partially filling vesicles, and giving a singularly perfect black cross under crossed Nicols.

Topographical and Geological Terms used locally in South Africa.—Report of the Committee, consisting of Mr. G. W. LAMPLUGH *(Chairman)*, Dr. F. H. HATCH *(Secretary)*, Dr. G. CORSTORPHINE, *and* Messrs. A. DU TOIT, A. P. HALL, G. KYNASTON, F. P. MENNELL, *and* A. R. ROGERS, *appointed to determine the precise Significance of Topographical and Geological Terms used locally in South Africa. (Drawn up by the Secretary.)*

DURING the year a long list of terms, mainly of Dutch origin, was received from Mr. A. Du Toit. This list contained contributions from Mr. A. R. Rogers. A list of words was also received from Mr. Kynaston and a small one from Mr. F. P. Mennell. A few definitions have been contributed by Dr. Hatch.

Two classes of words are at present being catalogued :—

I. Topographical terms.
II. Names of rocks and minerals.

Most of the words hitherto catalogued are of Dutch origin, but some Kaffir and Bushman words have also been included. It may be found desirable to extend the scope of the Committee to other parts of Africa, and suggestions will be welcomed.

CLASS I.—*Topographical Terms.*

Aar—

Is the name given to any feature on the surface which is very long compared with its breadth. Applied to the outcrop of a dyke, to a low ridge of tufa, to a slight depression, or most frequently to a line of country characterised by a particular kind of bush.

Baai—

A bay on the coast, *e.g.*, Saldanha Baai.

Bak—

A basin or basin-shaped hollow.

Bank—

A low ridge rising suddenly, *e.g.*, Vaalbank.

Banken, plural of *Bank*—

A term used to denote a step-like feature, hence *banken* type of scenery, *e.g.*, in the high veld portion of the Lydenburg district of the Transvaal, due to alternations of harder and softer beds with a low dip.

Berg—

Mountain: the term 'de Berg' is especially applied to the great eastern escarpment of the Transvaal plateau.

Bosch—

Bush or wood, *e.g.*, Blaauwbosch.

Bult—

A low ridge with gentle and gradual rise and even outline.

Dam—

Reservoir or pond.

Dans—

A broad shallow valley, *e.g.*, Leeuwen Dans.

Donga—

A small ravine or wash-out caused by floods in soft ground.
A gulley or dry water-course with steep sides, synonymous with the Eastern terms *waddy* and *nullah*.

Draai—

A bend or turn (of a river or range).

Drift—

A ford or crossing of a river.

Duin, plural *duien*—

A sand dune.

Dwala—

A native term used in Rhodesia for a bare rounded knoll or ridge of rock.

Eiland—

Island, *e.g.*, Paarden Eiland.

Fontein—

A spring. Much used in place-names, *e.g.*, Bloemfontein, Wonderfontein, &c.

Gat—

A hole, *e.g.*, *Wonder-gat*, a term applied to a sink-hole in limestone formation. *Cyfergat*, a spot from which water trickles; a 'soak.'

Gouph (pronounced 'Coop')—

A Bushman word, meaning 'as dry as can be,' applied to a portion of the Western Karroo.

Heuvel—

A height or elevation, generally of small magnitude, *e.g.*, Klipheuvel.

Hoek—

(i) The area enclosed by a bend in a river.
(ii) The upper end of a valley shut in by mountains.

Holte—

A hollow or depression.

Hoogte—

A height or elevation generally of greater magnitude than a 'heuvel.'

Karroo—

A Bushman word *Kárú*, or *Gárú*, meaning 'dry as a bone,' applied to country like the central portion of Cape Colony (geologically or botanically).

Kastrel (literally Castle)—

A high peak or ridge, *e.g.*, Riebeck's Kastrel.

Kloof—

A gorge.

Knoppie—

A little hill or knob.

Kolk—

A very small flat or depression with a calcareous surface (name probably derived from *Kalk* = limestone).

Kom—

A basin-shaped hollow.

Kop, diminutive *Kopje*—

A peak or little hill (literally head), *e.g.*, Zwartkopje, Witkopje; hence *Tafelkopje*, a flat-topped or table-mountain type of hill; Spitzkop, a sharply pointed type of hill.

Kopjes Veld—

A track of country characterised by numerous little hills.

Kraal—

An enclosure for cattle or goats, also a native home or village; *e.g.*, Makapanskraal.

Krans or *Kranz* (often incorrectly written *Krantz*)—

The feature made by a hard rock in a precipice.
The precipitous face of an escarpment; *e.g.*, Kranskop, Kransberg.

Kuil—

A shallow valley or depression.

Laagte—

A very shallow valley in which the course of the drainage is ill-defined.

Mond—

Mouth (of a river).

Muur—

A wall or barrier.

Naauwte—

A narrow portion of a valley or constriction along a gorge.

Nek—

A high-level gap or pass in a range of hills, *e.g.*, Commando Nek, in the Magaliesberg.

Oog—

The 'eye' of a river, usually applied to the spring feeding a river, *e.g.*, in limestone areas.

Pan—

A depression below the general level of the country, and into which the drainage is directed.

Panneveld—

Country characterised by numerous pans.

Plaat—

A wide surface of bare rock, *e.g.*, of granite, *e.g.*, Klipplaat.

Plat Kop—

A flat-topped hill or mountain.

Pont—

A ferry; *e.g.*, Lindeque's Pont, on the Vaal River.

Poort—

A low gap or short narrow gorge intersecting a range of hills = 'water-gap' of American geologists (lit. gate); *e.g.*, Krokodilpoort, Komati Poort, &c.

Portje—

A little poort.

Put or *Puts*—

A pit or well.

Puut—

(i) A point on the coast, or (ii) a spur of a mountain.

Rand—

A ridge or steep escarpment, generally of no great elevation, *e.g.*, Rooirand (red ridge), Boschrand, Gatsrand, Witwatersrand (hence 'The Rand'), &c.

Randje—

The diminutive of *Rand*.

Rug, plural *Ruggen*—

A ridge or series of ridges. The 'Ruggens,' a very rugged and mountainous track in Cape Colony.

Sluit—

A ditch or water-furrow.

Spitz Kop—

A pointed or conical hill.

Spruit—

A small river or rivulet.

Strand—

A beach or strand.

Tafelberg or *Tafelkop*—

A table-topped mountain.

Toren—

A tower (applied to a pointed hill), *e.g.*, Babylon's Toren.

Veld (incorrectly *Veldt*)—

Open uncultivated country—
Bush veld (D., Boschveld), bush country. Sometimes called Low veld.
High veld (D., Hoogeveld), high plateaux, about 5,000 to 6,000 feet above sea-level.
Middle veld (D., Middelveld). The intermediate mixed country, between High and Low veld.

Vlakte—

'Flats,' a wide tract of flat country or plain.

Vlei (often spelled *Vallei* or *Valley*)—

A flat track of country or area of gentle slope which is periodically subjected to flooding; a wide pan of inconsiderable depth.

Vloer—

A 'floor.' This term has much the same meaning as *Vlei.*

Waterval—

Waterfall.

CLASS II.—*Names of Rocks and Minerals.*

Amandel Klip (almond-rock)—

Amygdaloidal lava.

Bacon-rock—

A term used by Barberton miners to denote the reddish cherty or jaspery variety of the banded ferruginous quartzite.

Banket—

A term applied to the Witwatersrand conglomerates on account of a supposed resemblance to an almond 'cake' made by the Boers.

Bantom—

A term used by alluvial diamond diggers to designate striped or banded pebbles (magnetite-quartzite or slate, or magnetite-jasper rocks).

Bar—

A term used by miners to denote a conspicuous band or seam of rock, distinguished by some character such as hardness or colour, *e.g.*, Red Bar.

Blaauw-grond (blue ground), Kimberlite—

The unoxidised portion of the filling of the diamond pipes.

Blue Ground. See Blaauw-grond.

Bosjisman's Klip (bushman's rock)—

A term applied to the Dwyka of Southern Cape Colony owing to the jagged character of its weathered surface.

Calico-rock—

A term formerly used by the Marabastad miners for a banded magnetite quartzite, usually in alternating black and white bands.

Drip Kalk (drip-limestone)—

Stalactitic material.

Float—

A term used by miners for surface fragments—drift, rock not *in situ.*

Floating Reef—

A term used by diamond miners for the masses of the 'country,' or foreign rock occurring in a diamond pipe.

Gruis—

Shale, mudstone, or soft variety of Dwyka.

Haar Klip (thread-rock)—

'Crocidolite' or asbestos.

Hardibank—

A term used by diamond miners for a hard compact variety of 'blue-ground very resistant to weathering.

Ijzer Klip (ironstone)—

Applied most commonly to igneous rocks such as dolerite and diabase.

Kalksteen—

Limestone.

Klip—

A stone, or rock.

Olifant's Klip (elephant's hide rock)—

Name given to the Dolomite formation owing to its mode of weathering.

Ou-Klip or *Oude-Klip* (old rock)—

A secondary limonitic surface-deposit, a kind of laterite.

Turf—

A heavy black clayey soil or loam, very common in low-lying areas, overlying basic igneous rocks.

Vuursteen Klip (firestone rock)—

Quartz, chert, flint, or very fine-grained quartzite.

Yellow Ground—

A term used by diamond miners for weathered, decomposed, or oxidised 'blue ground' in the diamond pipes.

Investigation of the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, and at various localities in the East Riding of Yorkshire.—Interim 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, Dr. A. R. DWERRYHOUSE, Mr. F. W. HARMER, Mr. J. H. HOWARTH, Rev. W. JOHNSON, Professor P. F. KENDALL, *and* Messrs. G. W. B. MACTURK, E. T. NEWTON, H. M. PLATNAUER, CLEMENT REID, *and* THOMAS SHEPPARD. (*Drawn up by the Secretary.*)

IT was the intention of the Committee to have completed the work at Bielsbeck during the present summer, but owing to the field being under corn-crop further excavation was impracticable till after the harvest. No results therefore can be obtained before the date of the meeting, but the work will be carried on immediately after the coming harvest, and it is hoped that the final report of the Committee will be in readiness before the next meeting.

The Committee ask for reappointment and for power to expend the balance of the grant.

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.

Steady progress has been made with the indexing of the literature for the second portion of this Index (1801–1850). Among numerous works dealt with, the compiler, Mr. C. Davies Sherborn, specially mentions the following :—

Boisduval's works on Lepidoptera.
Publications of the Bologna Academy.
Bonaparte's numerous tracts and his 'Conspectus Generum Avium.'
Publications of the Bonn Natural History Society.
Publications of the Bordeaux Linnean Society.
Roret's edition of the 'Suites à Buffon.'

The number of index-slips increases with great rapidity, and continual effort is needed to keep this mass of material in order for reference. The slips already arranged constitute a mine of information for monographers and others. They are preserved in the Geological Department of the British Museum (Natural History), where reference is frequently made to them by members of the staff and outside workers, while information derived from them is often asked for by correspondents at a distance. The Committee would, however, be glad to see still more advantage taken of the facilities now offered for the consultation of this valuable aid to systematic work.

A copy of the first volume of the 'Index' is being shown in the Science Hall of the Franco-British Exhibition.

The Committee ask for reappointment, and earnestly hope that the full sum of 100*l.* will be granted towards the continued preparation of the 'Index Animalium.'

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*), Professors Sir E. RAY LANKESTER, A. SEDGWICK, *and* W. C. MCINTOSH, *and* Mr. G. P. BIDDER.

THE Committee report that the British Association table at the Zoological Station at Naples was occupied for ten months during the past session by Mr. Richard H. Whitehouse, B.Sc., of the University of Birmingham, and by Mr. C. C. Dobell, B.A., of the University of Cambridge. A short statement of the investigations they conducted at the station is given in their reports to the Committee given below. The Committee ask to be reappointed, with a grant of 100*l.*

Report of Mr. RICHARD H. WHITEHOUSE.

I occupied the table at the Naples Zoological Station for a period of six months (November 1907–May 1908). During the whole of the time

I was occupied in investigating the caudal fin of Teleostean fishes. I obtained about ninety species of fish in all, the majority of which were supplied in plenty. It is my intention to work out the whole of the collection as soon as possible in Birmingham. I fully anticipate that the results of the work will be of considerable value in this particular branch of study.

Report of Mr. C. C. DOBELL.

I have occupied the British Association table for four months this year—from March to June. During this time I have been chiefly engaged in studying the life-history of the Sporozoan parasites, which live alternately in Cephalopods and Crabs. (The parasites are those now usually known under the name of Aggregata.) In addition to studying the living animals in both hosts, I have been able to preserve satisfactorily a considerable amount of suitable material, so as to be able to further the work after leaving Naples.

Besides investigating the Sporozoan parasites I have also been able to carry out some researches upon the Infusoria (*Chromidina* and *Opalinopsis*) in the liver and kidneys of the cuttle-fish. I have succeeded, I believe, in arriving at a correct interpretation of the chromatin in these forms.

In addition, I have spent a part of my time in working upon the life-histories of the parasitic protists in *Aricia fœtida* and in *Lacerta muralis.*

Experiments in Inheritance.—Interim Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Mr. DOUGLAS LAURIE (*Secretary*), Mr. R. C. PUNNETT, *and* Dr. H. W. MARRETT TIMS. (*Drawn up by the Secretary.*)

On the Inheritance of Yellow Coat Colour in Mice.

Reasons for this Research.—The primary reason for this research is the unexpected result obtained by Cuénot on cross-breeding yellow mice with mice of other colours. On mating a yellow mouse with one that was grey, black, or chocolate Cuénot always found yellowness to act as a heterozygous Mendelian dominant to the other colour. When yellow F_1 hybrids so produced were intercrossed they gave an F_2 generation much in accord with expectation, being composed roughly of three yellows to one recessive. It is the gametic constitution of these extracted yellows which gives cause for surprise, and which is the essential point of importance. Eighty-one of them were tested by breeding, and it was to be expected that of these twenty-seven or so would be homozygous for yellowness, but not even one fulfilled the conditions of Mendelian purity. 'Or, à mon grand étonnement,' says Cuénot, ' je n'en ai pas trouvé une seule; les quatre-vingt-un souris étaient toutes également hétérozygotes.'[1]

This important and interesting result has attracted explainers of different schools. Morgan[2] makes it a text for emphasising his views about 'contamination.' Purity, in the Mendelian sense, he denies.

[1] *Arch. Zool. Exp.* (4), tom. iii., Notes et Revue, p. cxxix, 1905.
[2] *Science*, n.s., vol. xxii. pp. 877–879.

'Purity,' he says, 'is dominance over latency.' Cuénot, on the other hand, supported by Wilson and favoured by Lock, suggests that pure yellow-bearing germ-cells of both kinds are indeed formed by heterozygous yellow mice, but that there is a selective fertilisation; so that a yellow-bearing ovum and a yellow-bearing sperm are either mutually repellent or mutually sterile, though capable of fertile union with germ-cells bearing other colours. Or it may be that yellow is due to the association of several factors, as appears to be the case in certain colours of sweet peas investigated by Bateson, Saunders, and Punnett, and reported on by them to the Royal Society. Castle, discussing various alternatives, commits himself to none.

Further experiments are evidently most desirable.

Objects of the Research.—This brings me to the more precise aims of the present investigation, which are :—

(*a*) To repeat Cuénot's experiment with another strain of yellow mice.

(*b*) To test analytically, by as many different kinds of matings as possible, the gametic constitution of a series of yellow mice.

(*c*) To endeavour to produce a race of homozygous yellow mice.

Progress of the Research [*at present in initial stage*].—With the above objects I obtained, during December 1907, certain mice from sundry fanciers. These comprised (A) yellow mice, (B) mice of other colours to cross with the yellows.

(A) The yellow mice were three clear yellows (Castle's terminology), of which one was a male and the other two females, these mice are of an orange-yellow colour, their hairs containing yellow pigment only; there are also two yellows, which contained, in addition, a good deal of chocolate pigment associated with the yellow (Castle's sooty yellow); these I call *chocolate yellow*. I use the term *sooty yellow* to include all mice which, commencing life yellow, develop in their hairs later any other colour or colours in addition to the yellow. It will be convenient to follow the line of descent from a pair of the clear yellows. Clear yellow ♂ No. 15 mated with clear yellow ♀ 18 gave an F_1 generation of one clear yellow (♂ 45) and three blacks. Of this F_1 generation the clear yellow member mated with a chocolate gave two clear yellows and three blacks; this seems to imply that it contains black recessive. The same mouse (♂ 45) mated with a blue gave three yellow youngsters (of which one grew to a clear yellow adult, while the other two developed a considerable quantity of dark pigment, producing a blue colour associated with the yellow) and two blues; this seems to imply that it contains blue recessive. That is to say, ♂ 45 seems to contain both black and blue in the recessive condition. The black was probably derived through the father, ♂ 15, since a black youngster resulted from a mating of the latter with a sooty yellow (♀ 44) which had been shown to contain recessive chocolate. The source of the blue is not so clear; it is of course possible that it depends upon the presence or absence of a 'diluting' factor, blue being, as pointed out by Bateson, a diluted form of black.

Returning to ♂ 15 and ♀ 18, the clear yellow commencers of this pedigree, it may be noted that ♀ 18 has not littered further. Additional matings of ♂ 15 are :

(i.) With clear yellow ♀ 19, giving two yellows in which much dark pigment developed in the adult, producing in one of them a considerable resemblance to a wild grey. No mice of other colours appeared in this litter, but the number of young is too small to permit the conclusion that the female parent is homozygous for yellow.

(ii.) With a chocolate yellow, giving two yellows (colour of young) and one black.

(iii.) With another chocolate yellow (♀ 44) giving four yellows (of which one died before adult condition was determinable and the other three developed dark pigment) and one black.

Including the various kinds of yellows under one category, and summarising the results of matings involving yellow mice, I find that, so far, no yellow mice have certainly proved homozygous; that the result of mating yellow with yellow has been to give nine yellows and five of the recessive colour (black); and that matings of yellow with another colour have given twelve yellows and eight of the recessive colour.

(B) In addition to the yellow mice I obtained mice of other colours, of which pure races are necessary in order to test at all adequately the gametic constitution of the yellows.

(*a*) Chocolate mice.—These are particularly useful for testing purposes, as their colour is recessive to all others. Some chocolate mice were therefore obtained from various fanciers and tested. In all cases only chocolate has resulted from mating chocolate with chocolate. A large number of chocolate mice is desirable.

(*b*) A pair of blues were obtained from a fancier, and when mated together gave seven youngsters, all blues. Various blues have also appeared in mating black with black.

(*c*) Some blacks also were bought. Some of these were found to contain blue recessive; by appropriate breeding a race has been obtained which promises to breed true to blackness. An interesting result of mating black with black has occurred in one instance—the pair in question giving three youngsters which at sixteen days old are one of them black, one blue, and one chocolate; the matter is being investigated further.

(*d*) For greys I am using wild house mice. I shall also endeavour to obtain a true-breeding extracted race.

I refrain from discussing these initial results in detail until more material is to hand, as this would require an undesirable degree of speculation. For the present it is sufficient to point out—

1. That five of the six yellow mice which have so far been mated have proved to be heterozygous in respect of coat colour, in accord with Cuénot's result. The exceptional case of ♀ 19 is considered in section (i.) above.

2. There is nothing to contradict the order of dominance of the various colours as found by other investigators. In particular yellow is dominant to all other colours.

3. The occurrence of black, blue, and chocolate in one litter from a mating of black with black. Also the apparent presence in the recessive condition of both black and blue in ♂ 45 yellow.

4. The advisability of further classification of the various adult forms included under the term 'yellow,' and whose first coat is light yellow.

It will be seen that the experiments are at present in an initial stage—that the interesting stage is just being reached. Thus the clear yellow mice are in the third generation; pure races (so far as tested) of chocolate, blue, black, and grey have been obtained for mating with the yellows, and such matings should have commenced before this interim report is in print. The problem upon which it is sought to throw light will, I think, be recognised as one of importance in regard to the theory of heredity, and I anticipate that the present inquiry will lead to valuable results: that is to say, apart from any other points that may be raised, it will be of equal value either to confirm Cuénot's results or to obtain results different from his, and there is every prospect of one or other of these alternatives being fulfilled.

The Committee in submitting the above report desire to draw attention to the importance of enabling Mr. Laurie to continue his investigations. The amount granted last year has proved inadequate to meet the necessary expenses, and therefore they now apply to be reappointed with an increased grant.

APPENDIX.

Matings involving Yellow Mice.

	Parents					F_1 yellow		F_1 colours other than yellow
Both parents yellow.	Clear yellow	♂ No. 15	× clear yellow	♀ No. 18	=	1	...	3 blacks
	,,	♂ No. 15	× ,,	♀ No. 19	=	2	...	—
	,,	♂ No. 15	× choc. yellow	♀ No. 44	=	4	...	1 black
	,,	♂ No. 15	× ,,	♀ No. 43	=	2	...	1 black
						9		5
One parent yellow.	Clear yellow	♂ No. 45	× chocolate	♀ No. 41	=	2	...	3 blacks
	Chocolate	♂ No. 39	× choc. yellow	♀ No. 44	=	5	...	1 chocolate
	Clear yellow	♂ No. 45	× blue	♀ No. 38	=	3	...	2 blues
	Black	♂ No. 47	× choc. yellow	♀ No. 43	=	2	...	2 blacks
						12		8

The Zoology of the Sandwich Islands.—Eighteenth Report of the Committee, consisting of Dr. F. DU CANE GODMAN *(Chairman)*, Mr. DAVID SHARP *(Secretary)*, Professor S. J. HICKSON, Dr. P. L. SCLATER, *and* Mr. EDGAR A. SMITH.

IN December 1907 a part of the 'Fauna Hawaiiensis,' by Lord Walsingham, was published. It includes descriptions and figures of about four hundred new species of Lepidoptera. Another part of the 'Fauna' is at present in the press. It deals with Coleoptera, the authors being the Secretary and Mr. Hugh Scott. Dr. R. C. L. Perkins is preparing another part devoted to Coleoptera, and it is hoped that the work will be completed in about a year.

The Committee ask for reappointment without a grant.

The Fauna of the Lakes of Central Tasmania.—Report of the Committee, consisting of Professor G. C. BOURNE (*Chairman*), Mr. J. J. LISTER (*Secretary*), *and* Sir E. RAY LANKESTER, *appointed to assist* Mr. G. W. SMITH *to proceed to Tasmania to study the Anatomy and Development of* Anaspides, *and to investigate the Fauna of the Lakes of Central Tasmania.*

THE Committee have received the following report from Mr. G. W. Smith:—

The expenses of this expedition were defrayed partly by a grant of 40*l*. from the British Association, and partly by Professor G. C. Bourne, while New College, Oxford, by granting me leave of absence while holding a fellowship, made it possible for me to go.

The expedition was undertaken at the suggestion of Professor G. C. Bourne for the purpose of studying the freshwater fauna of Tasmania, and especially *Anaspides tasmaniæ*, the peculiar mountain shrimp only known to occur in one or two localities in Tasmania.

On arriving in Hobart at the end of September I made arrangements for living at a small chalet near the top of Mount Wellington, and by inquiring from the settlers in the neighbourhood and from Mr. Rodway, the original discoverer of *Anaspides*, I found out the chief localities where the mountain shrimp occurred. The locality where they were most abundant was in the pools of the upper reaches of the North-West Bay River, which rises near the top of Mount Wellington, about two hours' walk from the chalet where I was staying. I spent altogether six weeks on the mountain observing the habits of the animal in its natural state and making as accurate observations as possible on its anatomy. It was also possible to establish that the female deposits her eggs immediately after fertilisation, and that there is no complicated metamorphosis. The result of these observations, the main points of which are published in the 'Proceedings of the Royal Society,' June 24, 1908, is to vindicate the Anaspidacea as a primitive and separate order of the Malacostræa, showing affinities to several other orders, especially the Mysidacea and Decapoda, with many peculiar characters of its own. During my stay on the mountain I collected a number of other freshwater Crustacea, especially Amphipods of the genus *Neoniphagus*, the Isopodan genus *Phreatoicus*, and *Astacopsis*. I also made a study of the birds and obtained specimens of the characteristic kinds, while, with the help of Mr. Rodway, I became acquainted with the more interesting features in the flora.

Several expeditions were also made during this period, one to the tarns in the Harz mountains, where *Anaspides* was again met with, and a collection of the Entomostraca, &c., made, and another to Brunij Island with a camping party from Hobart, where some freshwater lagoons were investigated.

During Christmas week a camping expedition was arranged on Ben Lomond, a mountain in the north of the island, on the top of which are several small tarns, and the freshwater fauna of these, including various Entomostraca and Amphipoda, was collected. January was devoted to the lake district on the central highland plateau of the island. Two weeks were spent at the Great Lake, which proved to contain a very rich and interesting Crustacean fauna. In this lake a new genus and species of the Anaspidacea (*Paranaspides lacustris*) was discovered in some abundance living in the littoral zone. This species differs from *Anaspides tasmaniæ* in a number of characters correlated with its more active swimming powers; thus the body is transparent and sharply flexed, and the telson, uropods, and antennary scale greatly enlarged. Living with *Paranaspides* were three species of *Phreatoicus*, two of them hitherto undescribed, and a number of Amphipods, including the genus *Chiltonia*, which shows affinities to the South American *Hyalella*. Besides these a collection was made of the Entomostraca, Flat Worms and Molluscs. During my stay at the Great Lake I added several species to my collection of birds, and obtained some specimens of *Echidna*, *Platypus*, *Dasyurus*, and other Marsupials. From the Great Lake I made an expedition across country for about sixty miles, in a spring cart with two horses and a guide, to Lake St. Clair, the westernmost of the lakes and an exceedingly deep one, in places reaching down to ninety fathoms. As the tracts were either non-existent or else exceedingly rough, it took us two days to reach the lake. Dredging and tow-netting was carried on in the lake for two days, and some interesting Entomostraca and a few Worms were obtained, but on the whole the waters of the lake were very lifeless compared to the Great Lake.

On the way back a different route was taken, and the railway was reached at Apsley after three days' driving. One other lake was investigated afterwards, namely, Lake Sorell, and a collection made, especially of its Crustacean fauna, which differed considerably from that of the other lakes.

These collections are now being worked out, but the work has not yet reached a sufficiently advanced stage to report on any general results, though it is evident that the material will throw some light on problems of geographical distribution.

Besides several smaller expeditions to freshwater localities in the neighbourhood of Hobart and in the Midlands, I stayed for several days at Bridport, on the north-east coast, to collect specimens of the native freshwater fish, *Gadopsis*, *Aphritis*, &c., and also the huge *Astacopsis*, which in this district attains enormous dimensions. Some of the specimens obtained weighed over 6 lb., and were considerably over a foot in length.

At the end of February I went on to the west coast, and stayed in some of the mining districts, my object being to see the evergreen beach forests, which here almost entirely replace the gums, and to study, as far as possible, the fauna and flora and see something of the physical conditions.

Towards the end of March, I went to Melbourne and also to Sydney, and obtained from Professors Spencer and Haswell the loan of a large collection of undescribed Australian Crayfishes, affording material for a memoir on this little-known group.

As a result of the expedition I propose preparing the following for publication :—

1. A book entitled 'A Naturalist's Impressions of Tasmania.' Accepted by the Clarendon Press.

2. 'Preliminary Account of the Habits and Structure of the Anaspidiidæ.' Published 'Proc. Roy. Soc. Lond.,' 1908.

3. 'A Monograph of the Anaspidacea.' For the 'Quarterly Journal of Microscopical Science.'

4. 'The Freshwater Crustacea of Tasmania.' In the 'Trans. Linn. Soc. London.'

5. 'A Memoir on the Australian and Tasmanian Crayfishes.'

Occupation of a Table at the Marine Laboratory, Plymouth.—Report of the Committee, consisting of Professor A. DENDY (*Chairman and Secretary*), Sir E. RAY LANKESTER, Professor A. SEDGWICK, *and* Professor SYDNEY H. VINES.

SINCE the date of our last report, the British Association's table at the Plymouth Marine Laboratory has been occupied as follows :—

July 22 *to August* 1, 1907.—By Mr. C. H. O'Donoghue, who was engaged in collecting and preserving Hydrozoa for subsequent examination.

August 15–25, 1907.—By Mr. F. J. Bridgman, engaged in investigating the histology of calcareous sponges, &c., and in obtaining material for future work.

April 9–21, 1908.—By Miss H. L. M. Pixell, who was working at the physiology of digestion in elasmobranchs.

April 21 *to May* 4, 1908.—By Mr. F. J. Bridgman, for the investigation of special points in the histology of *Grantia compressa.*

Experiments on the Development of the Frog.—Report of the Committee, consisting of Professor G. C. BOURNE (*Chairman*), Dr. J. W. JENKINSON (*Secretary*), *and* Professor S. J. HICKSON. (*Drawn up by the Secretary.*)

THE Committee report that the statistical investigation into the relation between the spermpath and the plane of symmetry and the spermpath and the first furrow in the frog's egg is now approaching completion. Details cannot be given at present, but it is expected that a paper will be presented to the Section at the Dublin meeting.

Next year it is proposed to carry out an investigation into the alteration that takes place, during the development of the embryo, in the magnitude of the index of variability and the coefficients of correlation between various organs. The trout is a suitable form for the purpose, and may readily be obtained from a hatchery in the neighbourhood of Oxford. Some pecuniary assistance will, however, be necessary, and the Committee ask that the grant, which has been in abeyance during the past year, may be renewed.

Investigations in the Indian Ocean.—Third 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, Dr. H. R. MILL, *and* Dr. D. SHARP, *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 have received the following communication from Mr. J. Stanley Gardiner, who has had charge of the work :—

'I am now (June 29) *en route* to the Seychelles for the further prosecution of our researches. I expect to be there for twelve weeks, working mainly at the physical conditions of Mahé and Silhouette, two of the larger islands, which were scarcely examined during my last visit. I am accompanied by Mr. Hugh Scott and Mr. J. C. F. Fryer, both young Cambridge zoologists. Mr. Scott will devote himself to the entomology of the Seychelles, probably remaining in the group for at least six months. Mr. Fryer is to proceed to Aldabra, a ring-shaped island of some 45,000 acres, famous for its large land tortoises and peculiar birds, about 700 miles to the south by west of the Seychelles. Here he will remain for at least three months, investigating it in all its aspects, geographical, zoological, and botanical. He will also probably visit other islands under the Colonial Government, returning early in 1909. In the Seychelles I am promised the assistance of Mr. H. P. Thomasset, with whom I hope to collaborate in collecting the jungle floras of Silhouette and Mahé.

'During the present year three parts of volume i., "Transactions of the Linnean Society," of the results of the expedition of 1905 have been published. They contain the following papers :—Description of the Expedition, Parts I. and II. (J. Stanley Gardiner and C. Forster Cooper) ; On an Arboricolous Nemertean from the Seychelles (R. C. Punnett) ; Land and Freshwater Decapoda (L. A. Borradaile) ; Hymenoptera (P. Cameron) ; Odonata (F. F. Laidlaw) ; Fourmis des Seychelles, Amirantes, Farquhar et Chagos (Professor A. Forel), Pycnogonida (George H. Carpenter) ; Aves, with some Notes on the Distribution of the Land Birds of the Seychelles (H. Gadow and J. Stanley Gardiner) ; The Lithothamnia (M. Foslie) ; Note sur les Ixodidæ (Professor L. G. Neumann) ; Notes on the Coccidæ (E. Ernest Green) ; Stomatopoda from the Western Indian Ocean (L. A. Borradaile) ; and Pisces (C. Tate Regan).

'Reports have also been read at the Linnean Society on the Reptilia, Amphibia, and Freshwater Fish (G. A. Boulenger) ; The Antipatharia (C. Forster Cooper) ; The Gammaridea (A. O. Walker) ; Part of the Green Algæ (Mr. and Mrs. Gepp) ; The Stylasteridæ (Professor S. J. Hickson) ; Some Families of the Chætopoda (C. H. Potts) ; The Marine Nemerteans (R. C. Punnett and C. Forster Cooper) ; and the Madreporaria Fungidæ (J. Stanley Gardiner).'

The Exploration of Prince Charles Foreland, Spitsbergen.—Report of the Committee, consisting of Mr. G. G. CHISHOLM (*Chairman*), Dr. W. S. BRUCE (*Secretary*), *and* Major W. L. FORBES. (*Drawn up by the Secretary.*)

THE period of the work in the field was during July, August, and part of September in 1906, and during June, July, August, and September 1907. The persons assisting the author in the work during 1906 were Mr. E. A. Miller and Piper Gilbert Kerr; and during 1907, Mr. Stewart Ross, M.A., Mr. J. V. Burn Murdoch, Piper Gilbert Kerr, and Lieut. H. Johansen.

The work done was the topographical survey of the island by means of theodolite, sextant, compass, plane-table, &c.; and determining, as far as time and opportunity allowed, the geological features of the Foreland, and investigating the zoology, botany, and meteorology. The chief object was, however, the topographical survey, and other work was sacrificed to make this the more thorough. The result is the map I am able to lay before you now, on a scale of 1 : 100,000. It will be seen that practically the whole of the west coast is now accurately charted, and a very considerable part of the east coast; in fact, the only parts not thoroughly surveyed are small portions of the east coast between Murray Ness and Ferrier Haven, and between Ferrier Haven and Point Poole; the coast line of the south end of the island is also imperfect.

Practically the whole of the interior is mapped with minute accuracy, the position and altitude of the hills known, as well as their bases. Some parts—as, for instance, the vicinity of both the base camps of 1906 and 1907—can be accurately mapped on a scale of 1 : 10,000.

Prince Charles Foreland is about 49 miles long, varies from $2\frac{1}{2}$ to $7\frac{1}{2}$ miles in width, and has an area of about 271 square miles. It may be divided into three parts: a northern, mountainous part, extending from the north end 35 miles southward; then a very low-lying portion; and finally, another smaller hilly part, the south end. In a central part of the northern mountainous part the mountains have an elevation of over 3,000 feet, culminating in Mount Monaco (3,490 feet), and Mount Jessie (3,250 feet). This mountainous part is traversed by several cols and glens which connect the west and the east coast. The whole of the eastern slopes of the highest mountains are heavily glaciated, and several dead glaciers pass westward as minor branches. Between the foot of the mountains, which are more precipitous on the west, and the sea is a low-lying stretch of land from half a mile to two miles in width—a series of raised beaches—along which, on the west coast, one can travel for the whole length of the island. Similar beaches occur on the east coast. Nowhere do the mountains come right down to the sea except at Vogel Hook and Cape Sietoe. There are innumerable small rivers, only a few of which may at times be troublesome to cross. In the low land and in the glens and corries are many tarns and small lakes, many of which are typical rock basins. The low-lying part of the Foreland which cuts off the southern group of hills, viz. the Ross Heights from the northern mountain range is country similar to the low-lying land in Morayshire, Scotland, and has therefore been called Foreland Laichs.

Geology.—The rocks of Prince Charles Foreland consist, first, of a series of metamorphic crystalline schists, together with white and reddish quartzites, possibly connected, as regards age, with some fine earthy, laminated dark shales, in which we found no fossils. A hard grey limestone, having a weathered rough surface, may also possibly belong to this older series. Secondly, fossiliferous limestone, the fossils obtained from which have been carefully examined by Dr. G. W. Lee, of the Geological Survey of Scotland. Thirdly, flags of grey shale, containing the remains of dicotyledonous plants of Tertiary age, which Dr. Nathorst has been kind enough to examine and determine. The fossiliferous limestone has proved highly interesting, the fossils belonging to some horizon of the Carboniferous system, or possibly the Permo-carboniferous, whilst the others are Permian.

Fauna.—The mammals associated with Prince Charles Foreland and its seas are the Greenland, finner, bottlenose, and white whales; the Greenland whale being very scarce. The walrus was not seen by the Scottish Expedition; the only seals seen were *Phoca barbata* and *fœtida* in small numbers. On the land *Ursus maritimus* bones and fresh footprints only were seen, and two reindeer in 1906; there are many blue and arctic foxes.

Of the birds there are twenty-eight species, the most notable being *Xema Sabinii*, *Pagophilia eburnea*, *Colymbus glacialis*, *Alca torda*, *Calidris arenaria* (breeding), and *Somateria spectabilis.*

Flora.—There are fifty-five species of phanerogams, one fern, one equisetum, one lycopod, nineteen mosses, and four liverworts. Mr. R. N. Rudmose Brown points out that the flora is a purely European one.

Climate.—The temperature is high for so high an altitude, doubtless on account of the warm and open sea to the westward, which is mostly free of ice for four to six months. A dense canopy of clouds almost continuously covers the mountain tops, and often comes as low down as 100 feet from sea level, and not infrequently to sea level. Prince Charles Foreland bears the brunt of the westerly weather and protects parts of the mainland to the east, which consequently are blessed with far more sunshine and less cloud.

The interest of this survey lies in the fact that Prince Charles Foreland has been known for more than three hundred years, and has never been surveyed. Its uncharted coast has been a difficulty and danger to navigators especially on account of prevailingly foggy, and often windy, weather. The quantity of material from shipwrecks on the island tells a vivid tale of the past. These are sufficient reasons to account for the island not having been surveyed previously, as one often has to wait days, and not infrequently weeks, on account of rain and snow, wind and fog, without doing anything. The country is very rough for travelling over, which adds another obstacle. Captains, being timid of its reefy and unknown coast, keep a wide berth, and this makes landing and leaving difficult. The survey of the seas around this island is the next important part of the work, as well as the further study of the geology, botany, and natural history of the island and seas adjacent.

The Investigation of the Oscillations of the Level of the Land in the Mediterranean Basin.—Report of the Committee, consisting of Mr. D. G. HOGARTH (*Chairman*), Mr. R. T. GÜNTHER (*Secretary*), *and* Drs. T. G. BONNEY, F. H. GUILLEMARD, J. S. KELTIE, *and* H. R. MILL.

THE Committee have received the following report from Mr. R. T. Günther :—

1. I left England for South Italy in June 1907, and returned from Naples early in October 1907.

2. The principal objects of investigation were the indications of local alterations of the land level of the west coast of Italy beyond the limits of the Bay of Naples. Incidentally, however, the opportunity was taken to confirm past observations and to estimate with greater accuracy than heretofore the relation of the present mean sea level to certain marks upon the columns of the Temple of Serapis at Pozzuoli.

3. The localities examined included every rocky headland and beach of importance between Reggio di Calabria and Pæstum. Measurements of alterations of level of especial value were obtained at or near Palmi and Gioja Tauro, at Tropea, at Pizzo Amantea, Diamante, Praia, Sapri, Pisciotta, and elsewhere. To the north of Naples indications of post-Roman changes of land level were obtained at Formia, Gaeta, Sperlonga, Terracina, and Monte Circeo.

4. Although I still hope to be able to visit Italy before publishing the results of the investigation, it may be considered that the object for which this Committee was appointed is accomplished.

Gaseous Explosions.—First Report of the Committee, consisting of Sir W. H. PREECE (*Chairman*), Mr. DUGALD CLERK *and* Professor BERTRAM HOPKINSON (*Joint Secretaries*), Professors BONE, BURSTALL, CALLENDAR, COKER, DALBY, H. B. DIXON, HELE-SHAW, SMITHELLS, *and* W. WATSON, Dr. HARKER, Lieut.-Colonel HOLDEN, Dr. PETAVEL, *and* Captain SANKEY, *appointed for the Investigation of Gaseous Explosions, with special reference to Temperature.*

General Scope of the Report.

To engineers the investigation of gaseous explosions is chiefly of interest because of its bearing upon the theory of the internal combustion engine. The Committee have hitherto considered it mainly from this point of view, conceiving that a limited interpretation of their reference would be necessary if their labours were to lead to any result within a reasonable time, and that the limitation adopted should be determined by the fact that the Committee was initiated by the Engineering Section. On the other hand the work has been by no means entirely, or even mainly, of a practical as distinct from a purely scientific character. Many questions of a kind that might properly engage the attention of the Chemical and Physical Sections have been raised and discussed, and full scope has been given to the varied skill and knowledge possessed by the different members of the Committee, among whom, in addition to engineers, there are several whose interests are mainly in the direction of pure science. The test of practical value or interest has only been applied for the purpose of selecting from among the large number of questions arising in connection with explosions those which are proper subjects for investigation by this Committee, not with the idea of limiting such investigation to the practical aspect of these questions.

Seven meetings of the Committee have been held, and they have been excellently attended. At each meeting one or more notes written by members of the Committee have been presented and have formed the basis of the discussion. The following is a list of these notes :—

No. 1.	General Introduction	Dugald Clerk.
No. 2.	Dissociation of Steam and Carbonic Acid	Dugald Clerk.
No. 3A.	Measurements of Internal Energy of Gases up to 1400° C.	B. Hopkinson.
No. 3B.	Explosion Pressures as a Means of Determining the Energy Function of Gases	B. Hopkinson.
No. 4.	Dissociation and Specific Heat of Steam and Carbonic Acid, and Comparison of Gas-thermometers at very High Temperatures	J. A. Harker.
No. 5.	The Temperature of the Walls of a Gas-engine Cylinder	E. G. Coker.
No. 6.	The Deviation of Actual Gases from the Ideal State, and the Experimental Errors in the Determination of their Specific Heats	H. L. Callendar.

The essential feature common to the operation of all gas-engines is the conversion of a mixture of inflammable gases, by combustion or explosion, into a mass which consists in all practical cases of a mixture of steam, carbon dioxide, nitrogen, and excess oxygen. The performance of the engine depends primarily on the change in pressure or volume, or both, resulting from this chemical transformation, and on the properties of the products of the transformation after they are formed. It depends in only a secondary degree on the nature of the chemical process and on the velocity with which it takes place. These matters, important though they must be in any investigation of explosions and in the theory of the gas-engine, are not of the first importance. The foundation must be a knowledge of the properties of the gases enumerated above at the temperatures occurring in the gas-engine—that is, between 1000° and 2500° C. This report, therefore, consists mainly of an analysis of the present state of knowledge on this subject, together with suggestions as to the directions in which further research may be undertaken with the object of advancing it. It will be found, however, that as the mechanism and the velocity of combustion must be taken into account as disturbing factors when applying our knowledge of the gases in the theory of the gas-engine, so they enter into many of the experiments on which that knowledge is based, and some discussion of them is indispensable in any criticism of these experiments.

Thermodynamic theory shows that the physical properties of a gas in chemical equilibrium are completely specified when—

(1) The relation between the pressure and volume at constant temperature is known, and

(2) The internal energy per unit volume is given as a function of the temperature and the density.

The energy of a gas per unit of mass at temperature θ is usually defined as $k\ (\theta-\theta_0)$, where θ_0 is the standard temperature from which energies are reckoned, and k the mean specific heat at constant volume between the temperatures θ_0 and θ. The second of these data is therefore equivalent to a knowledge of the specific heat in terms of the temperature and density. This form of statement is probably more familiar; but, for reasons given later on, it is in many ways less convenient than that based upon the energy function.

For those gases with which we have to deal it may be assumed that the first relation is that given by Boyle's Law. Experiment and theory alike point to the conclusion that deviation from this law only occurs when the density of the gas departs widely from its normal value, and that it is diminished by high temperature. In the gas-engine the density of the gas rarely exceeds ten times that of the atmosphere, a point at which the deviation from Boyle's Law in air (at 100° C.) is only about one-half per cent.[1]

It is usual to make the further assumption that the product pv is proportional to the absolute temperature θ. A detailed examination of the grounds of this assumption forms the subject of a section of this report. At this point it is only necessary to notice that, if it be true, then the internal energy is a function of the temperature only, and is independent of the density. If, on the other hand, the perfect gas-law does not hold, then the true relation between pv and θ can be deduced from a knowledge of the internal energy, which is in that case a function both of the temperature and of the density.

The properties of the gases with which we have to deal are therefore completely defined when the energy has been tabulated as a function of the temperature and the density. So far as the present state of knowledge goes the energy is to be expressed in terms of temperature only; but an important part of future investigation must deal with its dependence on the density either by direct measurement or by a determination of the relation between pv and θ at high temperatures.

The prediction of the temperature reached in combustion, which must be the starting-point of any investigation of explosions, also rests primarily upon a knowledge of the energy function. For, subject to corrections for loss of heat, incomplete combustion, and work done while combustion proceeds, the thermal energy of the mixture of steam, CO_2, &c., after combustion is equal to the chemical energy of the gases from which that mixture was formed. The latter can be accurately inferred from the composition of the combustible gases, and, the thermal energy being thus known, the temperature can be calculated from a table of the energy function. The pressure or volume changes resulting from combustion can be deduced from the temperature by the use of the $p-v-\theta$ relations, which again ultimately depend upon the form of the energy function. A table of this function at high temperatures is therefore

[1] See Witkowski, *Phil. Mag.*, vol. xli. (1896), p. 309.

the first datum necessary for the investigations entrusted to the Committee, and is the principal subject of this report. Before proceeding to the discussion of this physical question, however, it is well to say something further about its bearing on practical engineering problems.

The first requisite for predicting the performance of a gas-engine is to know the rise of temperature and the consequent rise of pressure produced by the explosion. The importance of this need not be insisted upon; it is not only the principal factor in the mean pressure developed, it also determines in large measure the mechanical design of the engine and the necessary strength of its parts. The part played by the energy function in the calculation of this rise of pressure has been indicated in the last paragraph. In proceeding further to analyse the indicator diagram given by the engine with the object of accounting at each point for the heat which has been put in, a knowledge of this function is again required. The heat accounted for on the diagram is the work which has been done plus the heat contained in the gas. The latter item can be calculated from the temperature if the energy function be known. The balance unaccounted for, which it is usually the object of such investigations to find—whether in the steam-engine or the gas-engine—is the heat which has been lost to the walls or has been suppressed owing to incomplete combustion. In fact, the internal energy of the gases at high temperatures plays much the same part in the analysis of gas-engine phenomena as does the total heat of steam in investigating the working of the steam-engine.

Again, from a table of internal energy, it is possible to predict the pressure changes resulting from any series of operations such as occur in the gas-engine, one item in which is an explosion subject to certain hypothetical conditions which cannot be realised in practice, though they can be indefinitely approached. An ideal diagram of this kind, corresponding to the cycle of operations which is most usual in present-day gas-engines, can, for example, be constructed for any given combustible mixture on the assumption that the combustion is instantaneous and complete at the in-centre; that there is no loss of heat in compression, explosion, or expansion; and that during expansion the gases are at all times in thermal and chemical equilibrium. These conditions can never be completely realised, but can in theory be approached asymptotically by improvements in design carried on within certain defined limits—namely, that the degree of compression and the nature of the mixture are to be unaltered. For example, the heat loss may be reduced by increasing the size of the engine and altering the nature of the cylinder walls, and the attainment of thermal and chemical equilibrium may be promoted by reducing the speed. Such an ideal cycle is, in fact, precisely analogous to the Rankine cycle of the steam-engine, in that it takes account of the actual physical properties of the working substance, but leaves out of account such non-essential imperfections as heat loss to the cylinder walls. It represents an ideal which the real engine may approach indefinitely but can never attain; and the closeness of the approach is a true measure of the perfection of the engine.

The ideal cycle which has hitherto been used in discussing the performances of gas-engines is the well-known air-cycle. This is based upon a special assumption as to the form of the energy function—namely, that it is a linear function of the temperature at high, as it is known to be at low, temperatures. The specific heat of the working substance is taken to be constant and equal to 19 foot-pounds per cubic foot, or 4·8 calories per gramme molecule. In the state of ignorance as to the real form of the energy function which prevailed until quite recently, this assumption was as good as any other, since it was impossible to say that the value of the energy derived from it was further from the truth than any other value which might be assigned to it. So far as was known, the differences between the indicator diagram of a real engine and the corresponding air-cycle diagram might have been wholly, or almost wholly, due to what have been called above 'non-essential imperfections'—that is, to heat loss and to incomplete combustion. In other words, there was no conclusive evidence that the air-cycle was not for practical purposes a true ideal cycle in the sense defined above and equivalent to the Rankine cycle for the steam-engine. Under these circumstances its extreme simplicity made it the best available standard of comparison for judging the performance of a real engine. Recent researches, however, on the properties of the gases at high temperatures have definitely shown that the assumption of constant specific heat is erroneous, and have given sufficient information about the magnitude of the error to show that it is of material importance. They have shown that the air-cycle cannot be regarded as equivalent to the Rankine cycle in the steam-engine, inasmuch as it does not take account of the properties of the actual working fluid, but postulates a hypothetical fluid which has no real existence. It is as though in the theory of the steam-engine the total heat of the steam were to be taken as equal to its latent heat, the sensible heat of the water being neglected. This assumption would lead to a simpler formula for the ideal efficiency for the steam-engine, but it would be erroneous in the same way and to about the same extent as the air-cycle formula for the gas-engine.[1] The closer approximation to the real cycle which is made by taking account of the actual properties of the working fluid—in the steam-engine the total heat of the steam instead of only the latent heat, in the gas-engine the true value of the energy instead of that based on the assumption of constant specific heat—though it leads to some complication of formulæ gives compensating advantages of real practical value. It shows the engineer what are the limits to the improvements which can be effected by changes of design or increase of size, and it enables him to judge whether it is better that the lines of development should proceed in such directions or in the direction of radically modifying the cycle of operations.

Measurement of the Internal Energy or Specific Heats of Gases at High Temperatures.

The results of most experiments on the energy of gases have been expressed in the form of tables or formulæ giving the specific heat (referred to unit mass of the gas) in terms of the temperature. It would appear preferable for most purposes to exhibit them in terms of internal energy per unit volume. That is the form most convenient

[1] If the sensible heat of the steam can be neglected in comparison with its latent heat the Rankine cycle reduced to the Carnot cycle, with efficiency $\frac{T_1 - T_2}{T_1}$, for no heat is then necessary to warm the water from the condenser to the boiler temperature, and the whole process becomes reversible. The efficiency of the Carnot cycle usually exceeds that of the corresponding Rankine cycle by about one eighth part.

for purposes of thermodynamic calculation, and it has the further advantage that it expresses the actual quantity measured. In nearly all the experiments on the specific heats of gases the increase of energy in unit volume associated with a large rise of temperature is measured; and in most the lower limit of temperature is near that of the room. The rate of change with temperature, of the energy so determined, is sometimes called the 'true' or 'instantaneous' specific heat, and sometimes 'thermal capacity.' The Committee are of opinion that a definite name should be given to this important quantity, and they suggest the name 'volumetric heat,' which if adopted should include in its significance that the measurement to which it relates is made at constant volume, and is referred to unit volume of the gas. The term 'specific heat' could then be restricted to its usual meaning, which refers to unit mass of the substance. Convenience of calculation is promoted if the unit of volume taken is that corresponding to the gramme molecule under standard conditions which is sufficiently nearly the same for each of the gases under consideration and equal to 22·25 litres.[1] In this report internal energy and volumetric heat are expressed as calories[2] per 22·25 standard litres; and the zero of temperature from which the energy is reckoned (except where otherwise stated) is taken to be 100° C., in order that steam may be included on the same basis as the other gases. The results are conveniently exhibited as curves in which the energy is the ordinate, and the excess of the temperature over 100° C. is the abscissa. The slope of such a curve represents the volumetric heat C, and the ordinate divided by the abscissa for any temperature represents the mean volumetric heat from 100° C. to that temperature, here denoted by $\bar{C}$.

The experimental work done on this subject may be divided into three classes:—

(1) Constant-pressure experiments: Regnault, Wiedemann, Witkowski, Lussana, Holborn and Austin, Holborn and Henning. The gas is heated from an external source in these experiments, and is at atmospheric pressure.

(2) Experiments in which both volume and pressure are varied, the gas being heated by compression. The recent experiments of Clerk and the determinations of the velocity of sound in hot gas by Dixon and others belong to this class.

(3) Constant-volume experiment. To this category belong the explosion experiments of Mallard and Le Chatelier, Clerk, Langen, Petavel, Hopkinson, and others, and Joly's determinations with the steam calorimeter. In the explosion experiments the gas is heated by internal combustion.

[1] The volumes of the gramme molecule for the several gases are:—

H_2	22·24	CO	22·21
N_2	22·28	CO_2	22·08
O_2	22·22		

in litres at 0° C. and under a pressure of 760 mm. of mercury.

It may be noted here that 1 calorie per gramme molecule is equivalent to 3·96 foot-pounds per cubic foot.

[2] There is some difference in the energy value of the calorie according to the temperature at which it is measured. The difference between the maximum and minimum value over the range 0° to 100° C. amounts to about 1 per cent. This is of no importance for the purposes of this report, except in one or two places; but where it is necessary to be so precise the calorie at 15° C.—namely, the quantity of heat required to warm 1 gramme of water from 14½° C. to 15½° C.—is meant.

(1) *Constant-pressure Experiments.*

The constant-pressure experiments have been carried to a temperature of about 1400° C. The gas under atmospheric pressure flows steadily through a heater and then through a calorimeter, where it is cooled. The temperature just before entering and just after leaving the calorimeter and the quantity of heat evolved per gramme molecule of the gas are measured. This quantity of heat less the work done in the contraction, which is 1·98 times the fall of temperature, is the change of internal energy corresponding to that fall.

Regnault applied the method to air, H_2, CO, CO_2, and other gases over the range 0–200° C.

Wiedemann[1] repeated Regnault's experiments with some modifications of the apparatus. On account of the small range of temperature these experiments must be regarded as only giving the slope of the internal energy curve at the origin; but as they give this with an accuracy at least equal to that with which the ordinate is known at higher temperatures, they are of considerable importance in constructing the curve. The following table shows the values of the mean volumetric heat $\bar{C}$ over the range 0° to 100° C., found by these two observers for air, H, and CO. Witkowski's value for air, by the same method, is in exact agreement with Regnault's.[2]

	H_2	CO	Air
Wiedemann . . .	4·84	4·81	4·90
Regnault . . .	4·84	4·88	4·86

These results give a good idea of the accuracy attained in these experiments. In both sets the different observations ranged about $1\frac{1}{2}$ per cent. above and below the mean in each determination. Later work shows that the value of $\bar{C}$ for air is probably about 1 per cent. greater over the range 0 to 200 than over the range 0 to 100. Regnault was unable to detect this difference though he looked for it.

The volumetric heat of air has also been determined by Joly by means of the steam calorimeter. He found the specific heat of air at constant volume for the range 10° to 100° C. and at a pressure of about twenty atmospheres to be 0·172. There were distinct signs of an increase of specific heat with density, and assuming this to follow the linear law given by Joly the specific heat at normal density would be 0·1715, equivalent to 4·93 calories per gramme molecule. Professor Callendar points out, however, that this is based upon Regnault's number for the latent heat of steam which is of doubtful accuracy, and that more probably Joly's determination when reduced to the 15° calorie should be 0·1732, or 4·98 calories per gramme molecule. According to some unpublished experiments by a constant-pressure method, which have been made by Mr. Swann in Professor Callendar's laboratory, and in which it is believed that some sources of systematic error inherent in the earlier experiments of this type have been avoided, the volumetric heat of air is 5·0. These results are distinctly higher than those obtained by Wiedemann and Regnault, but the difference is of no importance for the present purpose except as an indication of the possibility of

[1] *Annalen der Physik*, 1876, vol. clvii.
[2] *Phil. Mag.*, vol. xlii. (1896), p. 5.

systematic errors in their method of experiment which may become important when it is applied to higher temperatures. It may be taken as fairly certain that the volumetric heat of air at 100° C. is within 2 per cent. of 4·9.

In the case of CO_2 the results obtained by Wiedemann and Regnault were :—

		W	R
Increase of internal energy	0 to 100	710	680
" " " "	0 to 200	1510	1490
" " " "	100 to 200	800	810

The first two rows of figures represent practically the quantities actually measured in these experiments.[1] The third is obtained by difference from the first two, and is therefore affected with a greater probable error than either. The result of the two sets of experiments may be summed up by saying that the volumetric heat of CO_2 at 100° C. taken as equal to the mean volumetric heat between 0° and 200° C. is between 7·45 and 7·55, and that its rate of increase with temperature is between 0·009 and 0·013, or roughly one six-hundredth part per ° C. The specific heat of steam at constant (atmospheric) pressure in the neighbourhood of 100° C., according to Regnault, is 0·48, equivalent to 6·64 volumetric heat, and subsequent observers have shown that this value is at least as accurate as Regnault's value of the specific heat of air.

From Joly's experiments with the steam calorimeter, when corrected according to Callendar for the error in Regnault's value of the latent heat of steam, the specific heat of CO_2 between 10° and 100° C. and at a pressure of 12 atmospheres is 0·172 and it increases by about 0·25 per cent. per atmosphere. Assuming this law of increase to hold between one atmosphere and 12 atmospheres, the mean specific heat at normal density for the range 10° to 100° should be 0·1666, and the volumetric heat should be 7·3, which is again decidedly greater than the values obtained by Wiedemann and Regnault. According to a recent determination by Swann, the result of which has been communicated to the Committee by Professor Callendar, the volumetric heat of CO_2 at 100° is 7·76—again materially higher than Regnault and Wiedemann (7·5).

Holborn in conjunction with Austin carried the constant-pressure determinations for air and CO_2 up to 800° C.[2] The gas was heated electrically and the temperature was measured with a thermo-couple. Similar measurements on steam were made by Holborn and Henning, who subsequently carried the determinations for the three gases up to 1400° C.[3]

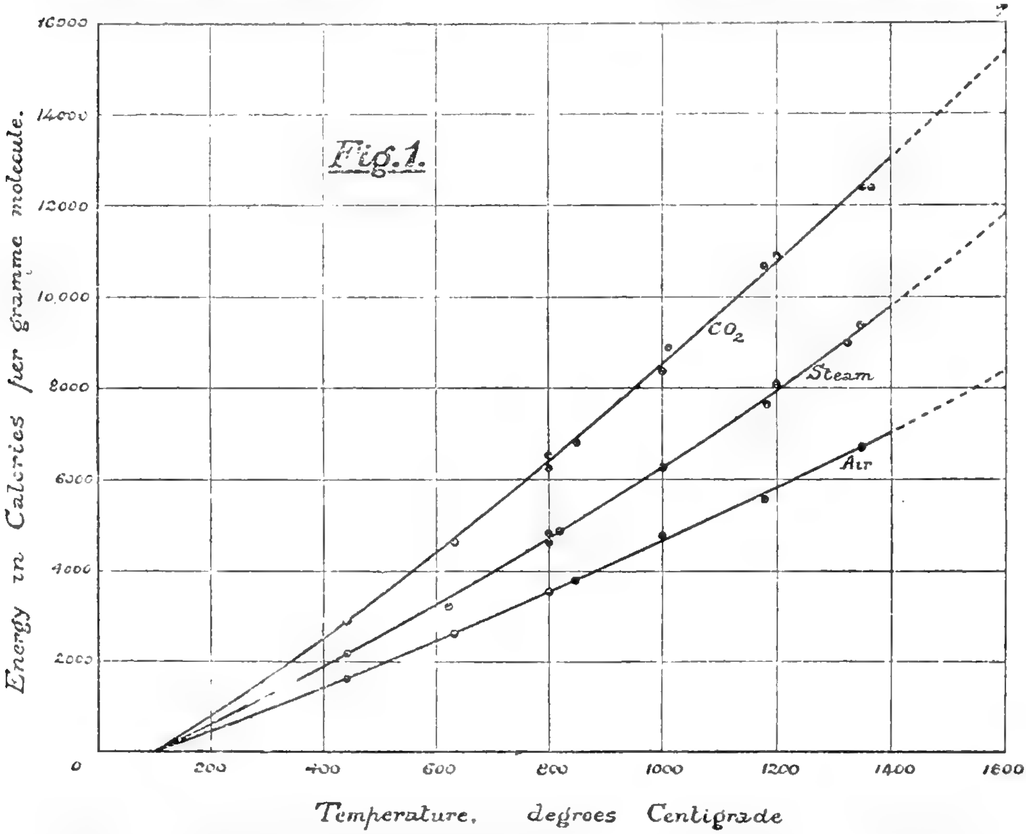
Holborn and Henning express the results of all these experiments in algebraical formulæ representing the mean specific heats of CO_2, air, and steam respectively over the range $0–\theta$ in the case of the first two gases, and $100–\theta$ in the case of steam. From these formulæ the full-lined

[1] The lower limit of temperature in Regnault's measurements was 10°, the upper limits were 100° and 210° respectively. In Wiedemann's work the lower limit was 25° and the upper 100° and 200° respectively. The results have been reduced to the forms here given on the supposition that the volumetric heat between 0° and 25° is 6·6, and at 200° 7·4. For the small additional range of temperature required these figures are certainly as accurate as the experiments.

[2] *Wiss. Abhandlungen der Phys. Techn. Reichsanstalt*, 1905.

[3] *Ann. d. Phys.*, **23**, 1907, p. 809.

curves in fig. 1, exhibiting the internal energy, have been constructed. The actual observations are also shown in the same figure. Each of these observations represents the mean of a large number of experiments, in some cases as many as thirty. The results of the individual experiments in such a group ranged about 2 or 3 per cent. above and below the mean. These casual errors would no doubt cancel out to a great extent in taking



the mean, which, apart from systematic errors inherent in the method of experiment, is probably correct within about 2 per cent.

This degree of accuracy is not sufficient to enable any deduction to be made as to the manner of variation of the volumetric heat beyond a rough estimate of its average rate of increase over the whole range of experiment. The following are the values of the volumetric heats of air, steam, and CO_2 at 100°, 600°, and 1100° respectively:—

—	100°		600°		1100°		Increase 100–1100
	C	γ	C	γ	C	γ	—
Air	4·9	1·404	5·2	1·38	5·75	1·345	0·9
Steam	6·6	1·30	6·85	1·29	8·5	1·24	1·9
CO_2	7·5	1·26	9·95	1·20	11·1	1·18	3·6

The corresponding values of γ are also shown: $\gamma = 1 + \frac{1·98}{C}$.

The values at 100° are derived from the experiments of Wiedemann and Regnault. Those at 600° and 1100° are based on the specific heat values given by Holborn and Henning; in other words, they are obtained by drawing tangents to the curves, fig. 1. The error at these higher temperatures may be double that of the internal energy, or, say, 4 per cent. The figures show that the volumetric heat of air increases by about ·0009, that of steam by ·0033, and that of CO_2 by ·0036 per degree centigrade over the range 100°–1100° C. There is no evidence that the rate of increase is other than constant in the case of air; but there can be no doubt that the average rate of increase between 100° and 1100° in CO_2 is less than half the rate of increase between 0° and 200°, as determined by Wiedemann and Regnault. There is also distinct evidence in these and other experiments that the rate of increase of the specific heat of steam becomes greater as the temperature rises.

(2) *Clerk's Experiments.*[1]

These cover about the same range of temperature as Holborn and Henning. The gas used was the products of an explosion in a gas-engine, and therefore consisted of a mixture of CO_2, steam, and air. It was first expanded in the ordinary course after the explosion, and was then heated by compression on the next in-stroke of the engine, the valves being kept closed for this purpose. On the next out-stroke the gas was again expanded, then compressed again, and so on, the valves remaining closed and the engine running on its own momentum. An indicator diagram was taken of the whole operation. The change of internal energy in any portion of a compression stroke (*e.g.*, B C in fig. 2) is equal to the work done less the heat lost to the cylinder walls; in an expansion stroke (C D) it is the work done plus the heat lost. The work can be obtained from the indicator diagram with an accuracy which is only limited by the indicating appliances. The change of temperature can also be calculated from the indicator diagram subject to a knowledge of the temperature at one point. Errors in the latter, however, do not greatly affect the results found for internal energy or volumetric heat, because the figure for the quantity of gas present is affected by these errors in such a way as to cancel out the error in temperature interval.

The loss of heat comes in as a correction on the work done and was estimated by a comparison of the compression line and the immediately following expansion line (B C and C D, fig. 2). The calculation is based on the assumption that the total heat loss from the hot gases during any given portion of a stroke is the same in expansion and compression if the mean temperature be the same.

In the first compression the temperature of the gas rose to about 1100° C. (at the point C, fig. 2). During the first three tenths of the following expansion stroke (C D), the temperature fell to about 700° C. The work done in this part of the expansion was measured and the heat loss determined as above was added. Thus the change of internal energy corresponding to the temperature change 1100°–700° is obtained. The average volumetric heat over this range is within the errors of experiment equal to the volumetric heat at the mean temperature of 900° C., which accordingly is by this method determined direct instead

[1] *Proc. Roy. Soc.*, A, vol. lxxvii.

of by difference, as is necessarily the case when (as in Holborn and Henning's experiments) the whole internal energy change associated with complete cooling of the gas is measured.

In view of the great difference in the method of experiment a comparison of Clerk's results with those of Messrs. Holborn and Henning is of great interest. Clerk's measurements extended to 1450° C., but those above 1200° C. were based on the first expansion line after the explosion when the method for getting heat loss would be of doubtful application, and when, moreover, combustion may have been incomplete. It will be better, therefore, to confine the comparison to temperatures of 1200° and below. The following table exhibits the internal energies of the mixed gas with which Clerk experimented calculated from Holborn

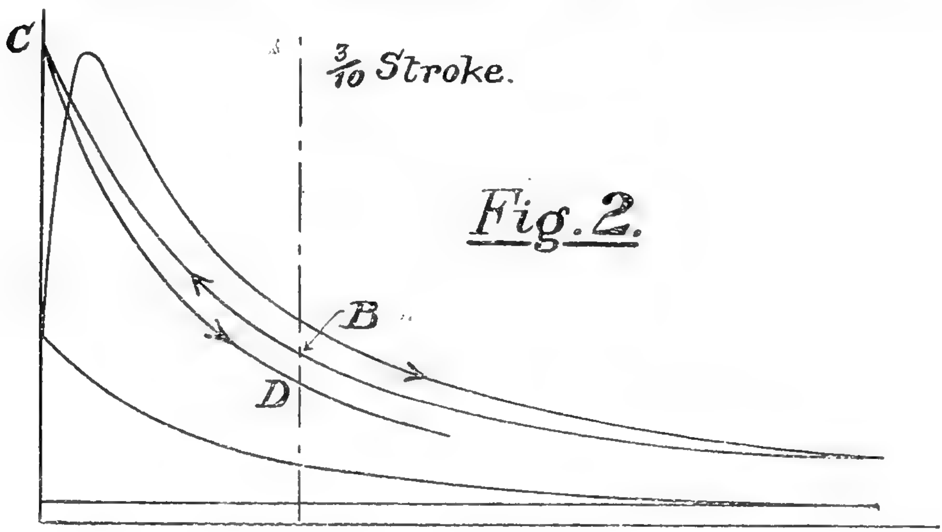


Fig. 2.

and Henning's figures, together with the energy calculated from Clerk's values for the mean volumetric heat. The energies are, as usual, reckoned from 100° C.; and the energies of an ideal gas with a constant volumetric heat of 4·9 are added for comparison.

Temperature	Holborn and Henning	Clerk	Ideal Gas
400	1580	1720	1470
800	3840	4300	3430
1200	6285	7040	5390

It will be seen that Clerk's results are throughout about 10 per cent. higher than the others. The difference between the energy of the real and of the ideal gas, the discovery of which is the true object of these experiments, is about twice as great in the one case as in the other. It does not seem possible to account for so large a discrepancy by ordinary experimental errors. It must be due either to some systematic error inherent in the method of experiment in one or both cases, or to a difference in the conditions of experiment giving rise to a real difference of internal energy.

Professor Callendar has favoured the Committee with a note dealing with the constant-pressure experiments. He is of opinion that the results obtained by Regnault's method are too low, and that at the higher temperatures reached by Holborn and Henning the error may possibly amount to as much as 10 per cent. In all these experiments there is a considerable flow of heat from the heater to the calorimeter. This, of course, has to be deducted from the heat registered in the calorimeter in order to find that which has been given up by the hot gas. All the experimenters by this method have determined the amount of this correction by observations when the gas was not flowing, or have compensated it under the same conditions by radiation from the calorimeter, making, in either case, the assumption that the amount of heat conducted is the same whether the gas be flowing or not. Professor Callendar is of opinion that this heat-flow is, in fact, much less when the gas is flowing. He considers that even the values obtained by Regnault may be as much as 2 or 3 per cent. too low, and he supports this contention by reference to the work of other experimenters (some of which has been alluded to above) and by theoretical considerations. As this type of error is likely to increase greatly with rise of temperature a systematic error of even 2 per cent. in Regnault's results, if established, would give reason to suspect that the experiments at high temperatures may be subject to errors of real importance for the present purpose.

If there be systematic error in Mr. Clerk's work it seems most likely that it lies in the estimate of heat-loss. The total heat-loss in the first partial compression and expansion line in the diagram (B C D, fig. 2) is estimated from the fall of temperature and from the net work done (area B C D) in the double operation, and amounts to, roughly, half the work done in expansion. This loss has to be divided between compression and expansion, and Mr. Clerk divides it on the assumption that if the mean temperature in compression and expansion were the same the heat-loss would also be the same. The mean temperature in expansion is, in fact, rather less than in compression, and the heat-loss calculated in this way is correspondingly smaller, but the difference on this account is not very great, and the result is, roughly speaking, that the loss is equally divided between the two operations. Thus the correction to be added to the work done in expansion in order to get the total loss of energy of the gas is about 25 per cent. of the work, or 20 per cent. of the energy change.

Professor Hopkinson has dealt with this point in a note which he communicated to the Committee, and he is of opinion that, relative to the mean temperature, the heat-loss is really much greater in compression than it is in expansion. He supports this view by reference to some experiments which he has made on the compression and expansion of a charge of cold air in a gas-engine which was motored round with the gas cut off. The specific heat of air being known, the loss of heat in any part of the compression or expansion stroke can in this case be independently estimated from the diagram. He found that while in the latter half of the compression stroke the heat lost to the walls amounted to a considerable fraction of the work done, some part of this loss was actually restored to the gas during the first half of the succeeding expansion, and this notwithstanding the high temperature of the air, which in expansion, as in compression, was much above that of the walls. An estimate of the thermal capacity could, of course, be obtained from this diagram by the application of Mr. Clerk's method, and it would lead to a result considerably in excess of the truth. Mr. Clerk has himself tried this same experiment of compressing and expanding air, and he also has found that the resulting value of the specific heat of air is too high and that the air takes in heat during expansion. Professor Hopkinson thinks it possible that the heat lost during the partial compression line in Clerk's diagram may be more than twice as great as the loss during expansion. If this were so, the correction for heat-loss in expansion would be less than 16 per cent. of the work done instead of 25 per cent., and the true change of energy would be less than that calculated on the assumption of equal heat-loss in compression and expansion by 7 per cent. or more.

It will be seen that the errors believed to affect each method of experiment are in such a direction as to account for the divergence of the results; and it is quite probable that when these errors are completely allowed for, the discrepancy will largely disappear. Meanwhile the internal energy of the products of combustion in the gas-engine at 1200° C., if taken as the mean of Clerk's and of Holborn and Henning's results, must be regarded as subject to a possible error of about 5 per cent.

Under these circumstances it does not seem necessary to discuss the possibility that there may be a real difference between the energy values obtained by the two methods due to the different conditions of experiment. It may be pointed out, however, that Clerk's gas was at the maximum temperature from fifteen to twenty times as dense as Holborn and Henning's. This difference in the condition of the gas is such that a comparison of the results obtained by the two methods, when freed from experimental errors, will be of great interest and importance.

(3) *Explosion Experiments.*

If a combustible mixture of gases be fired in a closed vessel impervious to heat, and if sufficient time elapse to allow of the attainment of complete thermal and chemical equilibrium, the internal energy of the products of combustion after the explosion will be equal to the chemical energy before explosion. The latter is capable of accurate measurement. The temperature reached after explosion can be inferred from the pressure, assuming the gaseous laws to hold. The pressure can also be measured without difficulty and with considerable accuracy.

In the study of explosion pressures we have therefore a very convenient and simple means of getting the internal energy function at high temperatures, provided that it is possible to make the necessary corrections for deducing from the pressures observed in a real explosion the pressure reached in an explosion under the ideal circumstances postulated above. Moreover, the gaseous laws on which the temperature estimations are based can themselves be checked, and if necessary corrected, by comparison of the pressures reached by mixtures of the same composition but of different densities. Thus explosion experiments are capable of furnishing a complete account of all the thermal properties of gases at the temperatures reached by combustion, subject always to the possibility of making the corrections referred to above. The difficulty of finding these corrections is, however, very great, and in consequence of the uncertainty which prevails even as to their order of magnitude, the large amount of work which has been done on explosion pressures gives but little definite information as to the specific heats of gases. Nevertheless, it is to the study of explosion pressures that we owe such knowledge as we possess of the energy function at the temperatures which prevail in the gas-engine, and it is to work on these lines that we must look in large measure for extension of our knowledge. A full discussion of what has been done already must therefore form an important part of this report.

Let H be the calorific value of the mixture before combustion, let h be the heat lost at some point A on the record (taken on a revolving drum) connecting the pressure and the time (fig. 3). The energy in the gas is then $H - h$. The gas at this point is, however, certainly not in thermal equilibrium, and is probably neither in chemical equilibrium nor at rest. If, therefore, the loss of heat were suddenly arrested at A the pressure would change owing to the more or less gradual attainment of equilibrium in all three respects. The equilibrium value of the pressure would be reached asymptotically, as shown by the dotted line. When

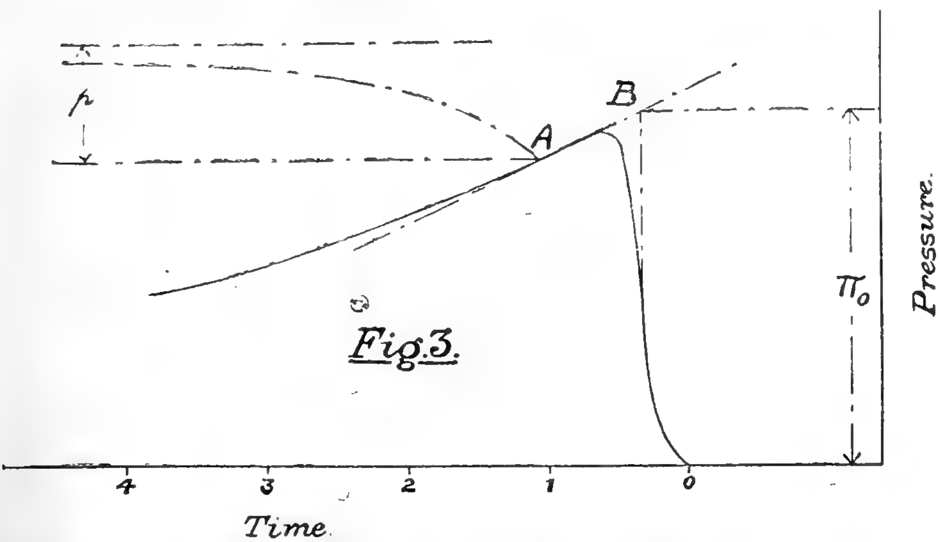


Fig. 3.

equilibrium has been attained the energy of the gas is all thermal and equal to $H - h$, and the temperature can be calculated in the ordinary way from the pressure. The problem, therefore, is first to find or estimate the heat loss h which has occurred at some point on the explosion record, and then to find or estimate by how much the equilibrium value of the pressure, if there were no further heat-loss, would differ from that shown on the record.

This change of pressure, marked p on the diagram, is due partly to the combustion of the gas remaining unburnt at A and partly to the equalisation of temperature by convection. It may also be due to some extent to the damping-down of the motion of the gas set up by the explosion.

The sooner the point A is taken, the less will be the loss of heat; but the greater, on the other hand, will be the departure from equilibrium conditions. The principal workers in this field, Mallard and Le Chatelier and Langen, assumed that the latter might be neglected if the point A were taken at the point of inflexion on the falling curve, and they estimated the loss of heat by prolonging this curve backwards, as shown. They assumed, in fact, that the pressure given by the point B was that which would ultimately have been reached had the explosion taken place in a vessel with walls impervious to heat.

It is difficult to justify this procedure on *a priori* grounds; the only satisfactory justification is to show, by independent evidence, that it leads to correct results. The main object of this section of the Report is to examine such evidence as there is of this kind, to point out the defects in it, and to suggest experimental methods by which they could perhaps be remedied.

In so far as the heat-loss and the departure from equilibrium are dependent on surface phenomena, a definite estimate of their amount can be obtained by a comparison of explosions of the same mixture in vessels of different sizes.

Many years ago Berthelot tried this experiment, firing hydrogen and oxygen, in explosive proportions, in vessels of 300 c.c. and 4000 c.c. respectively. It is stated that the pressure reached was very nearly the same, which would show that such part of the cooling and other corrections as depends on the surface of the vessel is small in the case of this mixture.

Materials for a more accurate comparison are to be found in the extensive researches of Mallard and Le Chatelier, and of Langen. The French experimenters worked with a cylindrical vessel 17 cm. × 17 cm., whereas Langen used a sphere 40 cm. diameter. The ratio $\frac{\text{surface}}{\text{volume}}$ was 2·3 times as great in the first as in the second case.

The following table shows the results obtained in two instances, in each of which the composition of the mixture was practically identical in the two sets of experiments:—

Mixture	Observer	Π_0	Cooling correction
2 vols. air 1 vol. (H_2+O)	Mallard and Le Chatelier, Langen	7·40 7·50	14 per cent. 8 "
2 vols. air 1 vol. $(CO+O)$	Mallard and Le Chatelier, Langen	7·50 7·50	$7\frac{1}{2}$ " 8 "

Π_0 is the pressure reached in the explosion in atmospheres after correcting for cooling in the manner described above, when the initial temperature is 0° C. The cooling correction, or excess of the pressure at B (fig. 3) over that at A, is shown in the last column. Figs. 4 and 5, which are taken from Langen's paper, show a comparison between the curve adopted by Langen, as representing the results of his experiments, and Mallard and Le Chatelier's observations.

On the whole the agreement between the two sets of experiments is very fair, and the deviations are not such as to suggest that any very great error has been made in estimating such part of the corrections for heat-loss or for unburnt gas as depend on the surface of the vessel. If, for example, Langen were, on the average, 4 per cent. out from this cause, Mallard and Le Chatelier would be 9 per cent. out, and would differ by 5 per cent. from Langen. Differences of that amount do occur, but they do not seem to be systematic. Further experiment of the same kind on vessels with a greater difference of size but of similar geometrical form is, however, desirable.

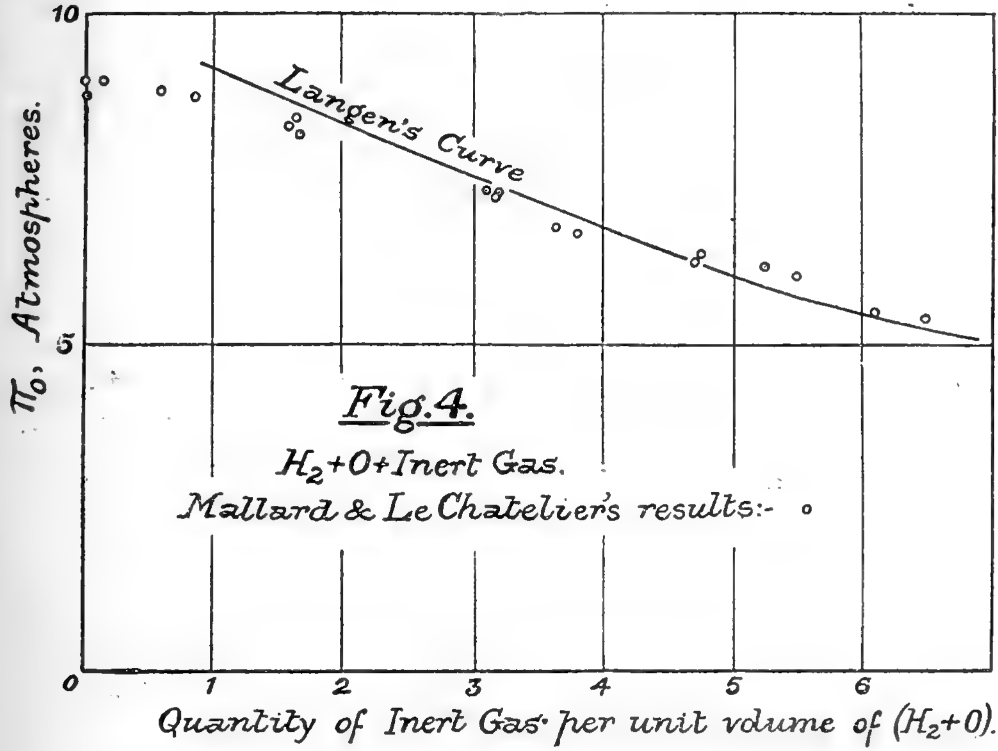


Fig. 4.

H_2+O+Inert Gas.

Mallard & Le Chatelier's results:- o

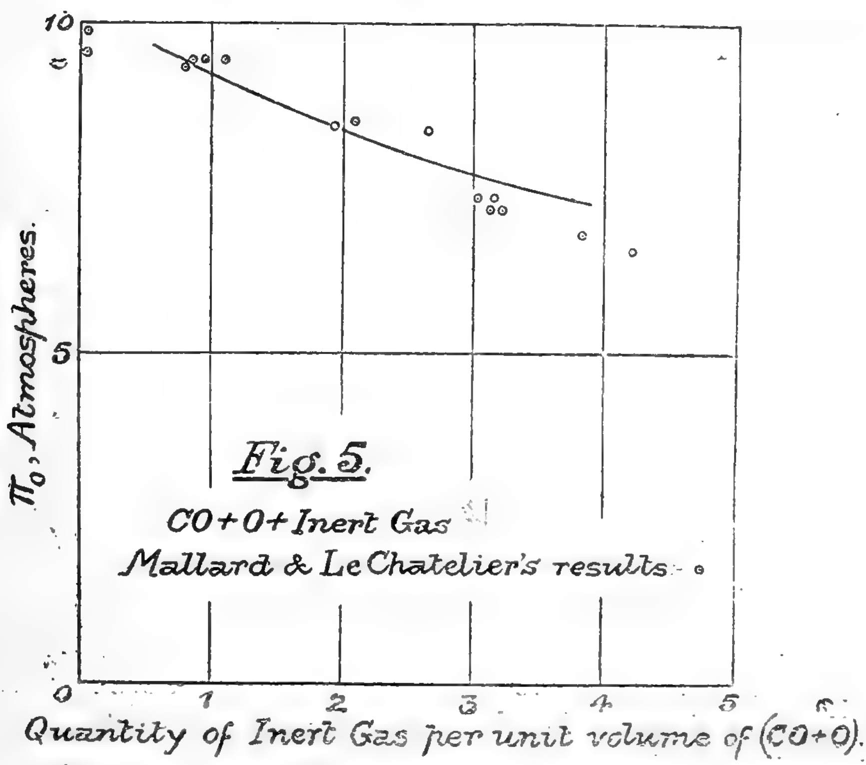


Fig. 5.

$CO+O+$Inert Gas

Mallard & Le Chatelier's results - o

The question remains, how far the corrections really are surface corrections. This appears to the Committee to be the most important question of a general character awaiting solution in connection with gaseous explosions when regarded as a means of investigating the properties of gases at higher temperatures. It will be convenient to discuss each of the corrections enumerated above with special regard to this question.

Loss of Heat.—That much of the heat-loss goes on by direct conduction to the walls, and is, therefore, a surface phenomenon, is obvious. But there is reason to believe that the loss by radiation, which certainly exists in any flame, is practically important.

(*a*) Measurements of the temperature reached in an explosion by means of a platinum thermometer, under circumstances which render very improbable any loss of heat by conduction from the gas whose temperature is measured, show that that temperature is considerably lower than is to be expected from the heat of combustion of the gases and the specific heat of the products. Professor Callendar pointed out, in the discussion of these experiments, that there was probably a good deal of radiation, and stated that he had found that an ordinary Bunsen flame might radiate up to 15 per cent. of its heat.[1]

(*b*) Recent experiments, in which the loss of heat during an explosion was directly measured by finding the rise of temperature of the walls, showed that in a certain coal-gas explosion it amounted to about 12 per cent. of the whole heat at the moment of maximum pressure. Estimated by Mallard and Le Chatelier's extrapolation method, the loss was at most 5 per cent.[2]

The prevailing opinion seems to be that most simple gases cannot be made to radiate by direct heating. If this be so the radiation must take place in the act of combustion. It seems very probable that when, say, hydrogen and oxygen combine a certain part of the energy of combination passes into the form of internal vibrations of the steam molecule, and that a large proportion, if not all, of this part is ultimately radiated away. If this be the case a definite proportion of the heat produced in combustion is always lost, and a comparison of explosions in vessels of different sizes would not reveal this loss.

Thermal Equilibrium.—When an explosive mixture of gases is ignited in a closed vessel the effect of the change of pressure during the progress of the flame from the point or points of ignition is to raise the temperature round about those points much above the mean temperature, and, on the other hand, the temperature attained at those places which are last reached by the flame, and where the gas is compressed before instead of after ignition, is much below the mean. Even in a vessel whose walls are impervious to heat the difference of temperature between the points first and last inflamed might amount to 700° C. at the moment of maximum pressure.[3] In a real explosion the cooling effect of the walls causes the temperature to range from perhaps 300° or more above the mean (as shown by the pressure) right down to the wall temperature at points close to the metal. The existence of large temperature differences in the gas close to the walls of an engine cylinder was first experimentally demonstrated by Professor Burstall with the aid of platinum thermometers.

If the volumetric heat of the gas were constant the equalisation of

[1] *Proc. R.S.*, A, vol. lxxvii. p. 400. [2] *Ibid.*, A, vol. lxxix. p. 147. [3] *Ibid.*, A, vol. lxxvii. p. 389.

these temperature differences by convection and conduction, could it take place without loss of heat, would cause no change of pressure. The volumetric heat is, however, not constant, but may quite possibly be 50 per cent. greater in the hottest than in the coldest part of the mass. The attainment of thermal equilibrium must, in fact, cause a change of pressure, and would contribute to the correction which has been designated p (see fig. 3). The amount of the change might be the subject of rough calculation, taking an assumed distribution of temperature and assuming values for the volumetric heat. Such a calculation in the present state of knowledge would only be of value as showing the possible order of magnitude of the quantity sought, and the assumptions made could therefore be of a character to make the calculation fairly simple. More accurate knowledge both of temperature distribution and of thermal capacity will enable greater accuracy to be attained in the estimation of this correction, which will be of such a kind that a method of successive approximation can be pursued, the revised values of thermal capacity resulting from its application being applied to a more accurate calculation of the correction if necessary.

The temperature variation set up by the cooling action of the walls is a surface phenomenon, and as such the correction which it necessitates can probably be determined and eliminated by experiments with vessels of different sizes. The variation caused by the change of pressure during the period of inflammation is not of this character; and the necessity for a large correction on this account is quite consistent with the observations of Berthelot, or of Mallard and Le Chatelier and of Langen. In these experiments the maximum pressure reached in the explosion was measured, and at the time of maximum pressure very large differences of temperature are known to exist at a distance from and quite independent of the walls.

Soon after maximum pressure, however, the temperatures at points remote from the walls are equalised to a large extent by convection currents. There then remains only the layer of gas near the walls to be considered in this connection. If, therefore, the measurements be postponed until a long enough time has elapsed to admit of this internal equalisation, the correction becomes of the surface kind, and can be dealt with by the method appropriate to corrections of that type. But in that case the heat lost will be too large a quantity to admit of rough estimation; it must be directly measured.

Chemical Equilibrium.—The view that chemical equilibrium is not attained until some time after the moment of maximum pressure was first put forward by Clerk in 1885, who then expressed the opinion that the greater part of the so called 'suppression of heat' in explosions was to be ascribed to this cause. On the other hand, Continental writers have almost completely ignored it. For example, Langen makes practically no reference to this in his paper. It can hardly be doubted, however, that in many explosions, especially of weak mixtures, a considerable amount of the energy is in the chemical form at the moment of maximum pressure. On the other hand it seems probable to the Committee that the amount of unburnt gas at this moment in such experiments as those of Langen was not such as to very greatly affect the results. This belief is based on the supposition that the incomplete combustion is due to the cooling action of the walls. It seems probable that very shortly after the attainment of maximum pressure—that is, within a time small compared with that required to reach maximum pressure—the transformation of the chemical energy into thermal form is everywhere complete except in a thin surface layer where this transformation is retarded by the cooling action of the walls.

If this view be accepted the correction of the results for incomplete combustion is of the nature of a surface-correction, and can be determined by comparing the pressures reached by the same mixture when exploded in vessels of different sizes.

In the discussion of this important matter the Committee have derived great assistance from the experience of Professors Dixon and Bone, who have made a special study of the velocity of chemical action in gases. These gentlemen are of opinion that though such action may be of great complexity, involving in many cases several successive molecular operations, yet, if it is not retarded by the presence of cold foreign bodies, it will generally be completed within a period which, for the purposes of gas-engine theory, may be regarded as negligibly small. In the simple case of the explosion of hydrogen and oxygen they consider that the complete transformation of the mixed gases into steam at any given point is complete within a time measured by the interval between molecular collisions. When the action is more complicated, as in the explosion of carbon monoxide and oxygen in the presence of water, or in the combustion of hydrocarbons, the period will be larger, but will still be measured by thousandths of a second.

Some direct evidence that incomplete combustion in an explosion is mainly, if not entirely, a surface phenomenon is to be found in Hopkinson's measurements of the temperature at points within a large explosion vessel by means of a platinum thermometer. A photographic record of the resistance of a fine platinum wire immersed in the gas showed that when the flame reached it the temperature rose in less than $\frac{1}{40}$th of a second from 20° C., which was the temperature of the unburnt gas, to about 1250° C., which was that of the burnt gas, and that it remained at the latter figure quite steadily except in so far as the increase of pressure in the vessel caused it to rise. In other words, there was no increase of thermal energy except that due to work done upon the gas from outside.[1] The mixture was one part of coal gas to nine parts of air—a slow burning mixture—and the time taken to reach maximum pressure was about a quarter of a second or at least ten times that required for combination of the gases at any one point. It is true that the vessel was of rather large size—about six cubic feet capacity—but, on the other hand, owing to the fact that the platinum wire extended over about 1 cm., so that the flame took an appreciable time to completely envelop it, it is probable that the period of $\frac{1}{40}$th of a second, given above, is a superior limit which greatly exceeds the actual time taken to effect the combination at any one point.

On the other hand, it cannot be doubted that combustion must be greatly retarded in the neighbourhood of the cold metal walls; and there is nothing to show that this surface retardation is not sufficient to account for all the phenomena of delayed combustion. A simple calculation based upon the rate of flow of heat per square foot into the metal of a gas-engine cylinder (which is roughly known from measurements of the heat carried away by the jacket water) shows that the

[1] *Proc. R.S.*, A, vol. lxxvii. p. 387

mean temperature of the exposed surface at points separated by an inch from the cooling water cannot exceed quite a moderate value. Probably about 200° C. is a superior limit for the cylinder liner. Similar calculation of a still rougher kind, but still sufficiently accurate to give the order of magnitude of the quantity sought, shows that the fluctuation above and below the mean in the course of a cycle is very unlikely to exceed 20° C. The latter conclusion has been confirmed by some experiments made by Professor Coker with a preliminary account of which he has favoured the Committee. Measuring the cyclical variation of temperature of the inner surface of a 12-h.p. gas-engine cylinder by methods similar to those adopted by Professors Callendar and Nicholson in their well-known work on the steam-engine, he found that the maximum was only 7° F. in excess of the mean. The direct measurements by Professor Hopkinson of the temperature of the walls of an explosion vessel lined with copper strip also lead to the conclusion that it is quite moderate. This cold metal must obviously profoundly affect the combustion in its neighbourhood. In a layer of gas of appreciable thickness the combustion will be of a smouldering character, depending upon the velocity with which the unburnt gas in contact with the walls can diffuse into the hotter regions at a distance from them, and so be brought to the ignition temperature. This layer being cold and highly compressed might account for a considerable fraction of the heat, though its actual thickness may be only a few tenths of a millimetre. It would appear probable that the continued burning which undoubtedly goes on after the time of maximum pressure in many explosions, and probably also occurs during the first portion at least of the expansion stroke of a gas-engine, is mainly of this character.[1]

Motion of the Gas.—In many explosions intense vibratory motions of the gas are set up. The effect of these sometimes appears with a quick-period indicator as a rapid variation of pressure. It is a question of some importance how these motions affect the *mean* pressure shown by a gauge. The damping-down of the motion which occurs in consequence of viscosity of course only means that the motion becomes distributed among the molecules in a random way, instead of following a definite arrangement. The total kinetic energy remains the same. But it is not certain that the mean effect on a pressure gauge of the molecular impacts will be the same. This is a question which might be considered by someone to whom the methods of the kinetic theory of gases are familiar. It is of course not a surface phenomenon.

Results of Observations.—The temperatures reached in these explosion experiments range from about 1300° up to 3000° C. Temperatures of below 1500° are, however, obtained by the use of weak mixtures, involving slow burning and large cooling corrections, and but little reliance can be placed on the results. Langen made very few observations on mixtures giving a lower temperature than 1500°, and takes that as the lower limit of the range of temperature to which his observations apply. The extreme upper limit of the constant pressure experiments is 1400°. The temperature of 3000° C. is about that reached in the explosion of hydrogen and oxygen in their combining proportions. This is much above the mean temperature ordinarily reached in the gas-engine, the

[1] Professor Bone is doubtful whether 'smouldering combustion' plays so considerable a part in gaseous explosions as is here suggested.

upper limit of which may be put at about 2000° C.; though it is probable that 2500° or more is occasionally reached locally. Langen, however, places the upper limit of the application of his formulæ at 1700° C., on the ground that there is dissociation of the CO_2 at higher temperatures than that. There does not seem to be much reason for this limitation, for the effects of dissociation (provided that equilibrium is attained) are indistinguishable from those of increasing specific heat, and should be included in the change of energy. Dissociation may give rise to errors in the temperature measurement, but there is reason to suppose that the dissociation which occurs in the CO_2 in steam at a temperature of 2000° C. is too small to cause any material change of volume, though it may mean considerable absorption of heat.

The formulæ given by Langen as representing the results of his observations are as follows :—

$$\begin{array}{ll} \text{Air} & \bar{C} = 4{\cdot}8 + 0{\cdot}0006\,t \\ CO_2 & \bar{C} = 6{\cdot}7 + 0{\cdot}00260\,t \\ H_2O & \bar{C} = 5{\cdot}9 + 0{\cdot}00215\,t \end{array}$$

where $\bar{C}$ is the mean thermal capacity over the range 0 to t° C. The explosion pressures predicted by the use of these formulæ agree well with the observed pressures except in the case of mixtures of CO and air, where they are a good deal too high. In the other cases the maximum deviation is about 4 per cent.

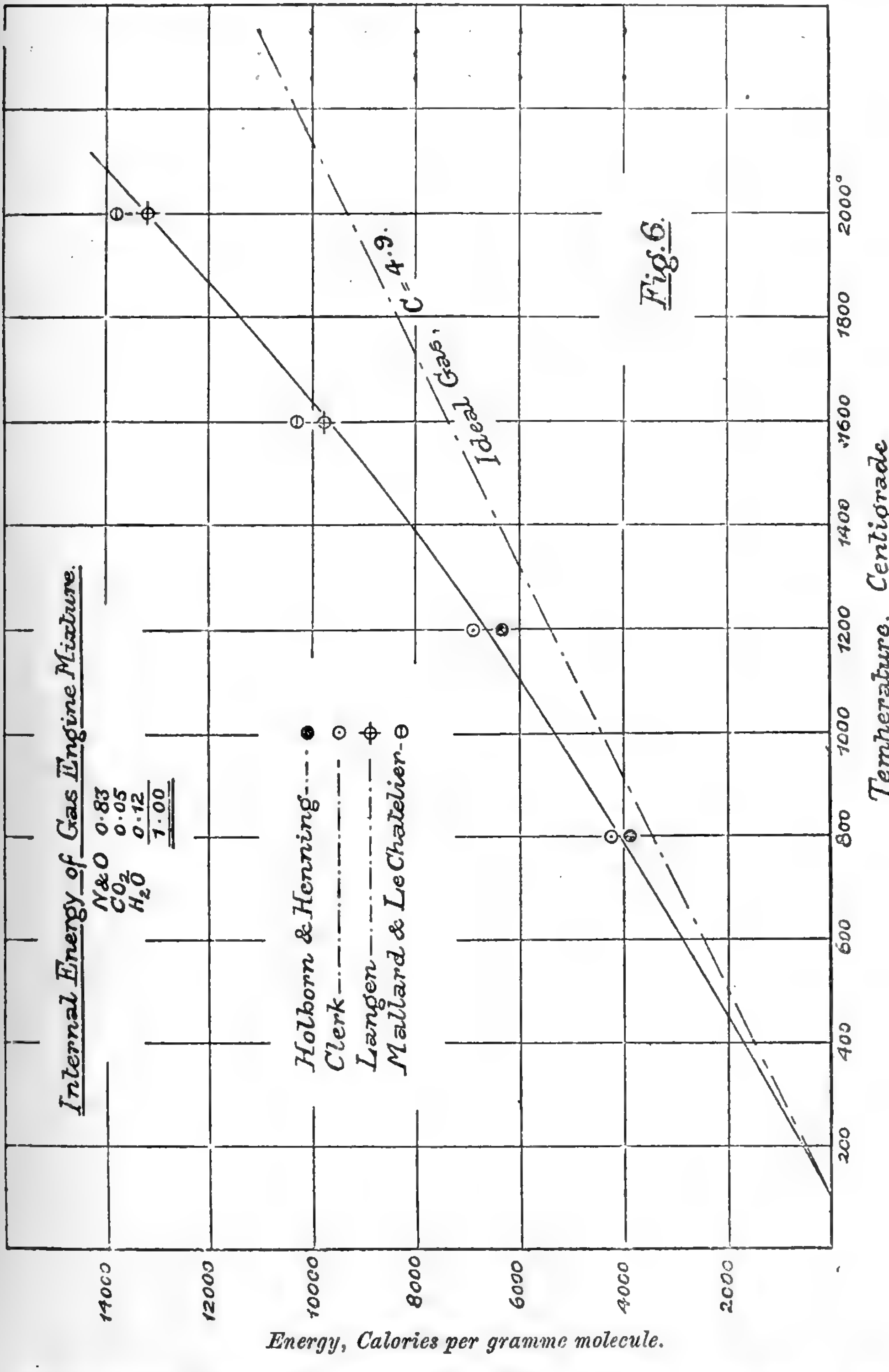
Mallard and Le Chatelier represent their results by formulæ which differ greatly from the above in the case of CO_2 and H_2O, though the formula for air is the same. This discrepancy must be due in some way to the method of reduction adopted, for, as already pointed out, the explosion pressures reached with mixtures of the same composition are very nearly the same.

Taking Langen's values, the following table exhibits the energy of the various simple gases, and of the mixture on which Clerk experimented, at 1600° and 2000° respectively. The energy of the same gases at 800° and at 1200° based on Holborn and Henning's and on Clerk's results is also given for comparison. The results are given in calories per gramme molecule. To reduce to foot-pounds per cubic foot multiply by the factor 3·96.

——	800°		1200°		1600°	2000°
——	Clerk	Holborn and Henning	Clerk	Holborn and Henning	Langen	Langen
Air	—	3570	—	5840	8700	11500
CO_2	—	6460	—	10880	17000	23300
H_2O	—	4670	—	7930	14400	19900
Gas-engine Mixture	4250	3840	6900	6340	9800	13200
Ideal Gas* . .	3430		5400		7350	9300

* C = 4·9.

The results for the gas-engine mixture are plotted on fig. 6, on



which points obtained by Mallard and Le Chatelier's formulæ are also shown.

The energy of gas-engine mixture at 1400° according to Clerk, Holborn and Henning, and Langen respectively would be as follows :—

Clerk	8300
Holborn and Henning	7700
Langen	8300

It will be seen that the agreement between Clerk and Langen is close, both being about 8 per cent. higher than Holborn and Henning. But it is to be observed that this temperature is just outside the range of all three sets of experiments.

The Committee are of opinion that values of the energy obtained from explosion records are not subject to any very great errors on account of heat-loss by conduction to the walls of the vessel, nor on account of incomplete combustion, but that they are affected by errors of quite unknown amount due, first, to heat radiated, and secondly to the want of thermal equilibrium at the time when the pressure is measured. For the purpose of testing the first of these conclusions, it is very desirable that further experiments should be made on explosions in vessels of greatly different size but of similar form. The opinion entertained by the Committee that incomplete combustion is a surface-phenomenon, on which this conclusion as to the validity of the method is based, also requires further confirmation. As regards the second conclusion further experiment on the actual amount of heat radiated by burning gas is urgently required, and also experiments to confirm or negative the effect of the nature of the wall surface upon the pressure reached in an explosion. The effect of want of thermal equilibrium can be determined up to a point by calculation ; but before such calculation can be usefully made, it is desirable that further information should be obtained as to the temperature distribution after an explosion, especially in the neighbourhood of the walls. It should not be difficult to get an idea of this sufficiently accurate for the purpose by means of platinum thermometers.

The most hopeful way, however, of making use of explosions to give definite information as to the properties of gases would appear to be to directly measure the heat lost in the explosion, as if this be done it is possible to defer the pressure measurement until such time as equilibrium conditions, except those that depend on the surface of the vessel, have been attained.

The Measurement of Temperature.

In all the experiments for the determination of the energy function which have been described above the measurement of the temperature is ultimately based upon the pressure or volume changes of the gas. In the constant-pressure experiments of Holborn and Henning the temperature of the gas before entering the calorimeter was measured by means of a thermo-couple which had been compared with a constant-volume nitrogen thermometer up to 1600° C. In the explosion experiments the mean temperature of a gas is inferred from its pressure. Similarly, in the analysis of the gas-engine diagrams, the gas is itself the thermometer. The mean temperature at any point is taken as proportional to the product pv, and the actual temperature at one point in the cycle (a knowledge of which is necessary for getting absolute values) is obtained either by estimating the quantity of gas present in the cylinder or by direct measurement with the platinum thermometer, as was recently done by Callendar and Dalby.

The temperature scale so obtained is probably sufficiently definite, at any rate for the purpose of gas-engine theory, since the mixture to which it is applied does not vary very greatly in composition, and always consists mainly of nitrogen. It is not so certain, however, that this scale agrees with the absolute thermodynamic scale; and the question of the possible amount of the deviations at temperatures of 1500° and over is of great importance in connection with the present inquiry.

So far as the Committee are aware, the experiments of Joule and Thomson still remain the only comparison between the various gas-scales and the thermodynamic scale: this comparison only extended to about 200° C., and is, of course, of no application to the problem now under discussion except in so far as it gives an idea of the differences to be expected at higher temperatures. What it really shows is that thermometers constructed of the more permanent gases are all so closely accordant with the thermodynamic thermometer as to lead to the belief (as a matter of induction, and quite independently of the kinetic or any other theory) that there is really some definite cause tending to make a gas, as such and apart from its composition, obey the law $\frac{pv}{\theta}=$constant. It would appear that the small deviations from this law, sometimes one way and sometimes the other, which are observed must be due to disturbing causes depending on the nature of the gas, whose influence may be in either direction and is of very various amount, but is at low temperatures small compared with the tendency to obey the perfect gas law. This view being accepted, there is a strong presumption that, if a number of thermometers constructed of different gases be compared at high temperatures and be found to agree fairly well, then they all agree with the thermodynamic scale at least as well as they agree with one another. It is upon the agreement between different gas-thermometers that our belief in the measurement of temperature is really founded, and, so far as it goes, the foundation seems to be sound.

The nitrogen thermometer has been used with an iridium bulb up to 1600° C.,[1] but no other gas has been taken above 1100° C. At the latter temperature the differences between thermometers constructed of hydrogen, nitrogen, and air are quite negligible for the present purpose. Rather more deviation has been observed in CO_2; but having regard to the small percentage of this gas which is ordinarily present in the gas-engine mixture, it is not likely that temperatures up to 1100° C., calculated in the usual way from the indicator diagram, will differ much from the true temperatures on the thermodynamic scale. 1100° C. is, however, not much above the lower limit of the gas-engine range; as to what goes on in the upper part of that range we have little or no evidence.

When considerable deviation from the gas-laws at high temperatures is observed in the case of any gas, it is usually ascribed to dissociation. For example, if comparison be made of two constant-pressure thermometers filled respectively with hydrogen and with iodine vapour

[1] Holborn and Valentiner, *Ann. d. Phys.* xxii. (1907), p. 1.

they will be found to agree up to about 1000° Abs.; the iodine thermometer will then begin to read higher than the hydrogen thermometer until, when the latter reads about 1800° Abs., the former will read about double that amount. When the gases are hotter still the temperature shown on the iodine thermometer will continue to be double that shown on the other. In this case the departure between the two thermometers is accompanied by a change in the absorption spectrum of the iodine vapour; and the whole phenomenon is expressed by saying that the iodine molecule has been split up or dissociated. In the case of a compound gas this dissociation sometimes takes the form of an actual separation of the constituents, which can be detected by diffusion. A great deal of experimental work has been done with the object of ascertaining to what extent the gases CO_2 and steam split up at high temperatures. These gases are constituents in most gas-engine mixtures, and if they dissociate to any considerable extent there will be a corresponding effect upon the $pv\theta$ relations of the mixture of which they form a part. So far, however, there is, in the opinion of the Committee, no conclusive evidence that either steam or CO_2 is dissociated to an extent which is material for the present purpose. Slight traces of dissociation have undoubtedly been found in both cases, but the method of experiment is such as to leave it doubtful how far these have been conditioned by the nature of the walls through which the dissociated gas is diffused. It must be observed, moreover, that CO_2 and steam usually form only a small part of the mixture in the gas-engine, and that therefore a considerable amount of dissociation of these gases would be necessary to produce much effect upon the pressure of the whole. Again, such dissociation, if it occurs, must have an effect upon the energy of the gas out of all proportion to the effect which it has upon its temperature. Take, for example, the case of a mixture formed by the explosion of CO and air and containing 10 per cent. of CO_2, the remainder being nitrogen. If, by heating, one tenth part of the CO_2 be split up into CO and oxygen, the resulting change of pressure of the whole mixture will be only one two-hundredth part; but this amount of dissociation could only be effected by the absorption of an amount of heat of the order of 10 per cent. of the total heat of combustion of the gas. In other words, the mean specific heat of the mixture, as determined by the explosion, would be roughly 10 per cent. lower than if there had been no dissociation. Any considerable departure from the gas-laws in such a mixture, if it be ascribed to dissociation at all, must therefore be put down to dissociation of the nitrogen, which might conceivably occur at 2000° C., just as iodine vapour is dissociated at a much lower temperature. It does not seem likely, however, that if nitrogen dissociates its splitting-up would be accompanied by any visible change in its physical properties, such as is observed in the case of iodine. The phenomenon in this case would be rendered evident only by the departure from the gas-law, and possibly by absorption of heat.

It would appear, therefore, that our knowledge of thermometry at these temperatures is more likely to be advanced by direct experiments on the relation between the pressure or volume and the temperature than by looking for other evidences of dissociation. The difficulty in carrying the comparison of different gas-thermometers to very high temperatures has hitherto lain in the absence of any material sufficiently refractory to withstand such temperatures, and at the same time sufficiently impervious to the gas. Dr. Harker, to whom the Committee are greatly indebted for much information upon this subject, believes, however, that he is now in possession of a material which will satisfy both of these conditions up to a temperature of 1800° C., and he has suggested that an attempt should be made to compare thermometers constructed with nitrogen, with CO_2, and with argon up to that temperature. If the nitrogen and argon thermometers are found to agree, then, by reason of the great difference in the constitution of these gases, it is almost certain, as explained above, that each agrees with the thermodynamic scale. If, on the other hand, they do not agree, then the presumption is in favour of the argon thermometer, because this gas is supposed to be monatomic and to be incapable of dissociation. The Committee venture to express a hope that a research on these lines will be commenced and carried to a conclusion. They believe that the results obtained will be of very great importance in the investigation of explosions and in the theory of the gas-engine, and it seems to them an inquiry eminently fitted for the National Physical Laboratory.

The comparison of gas thermometers is, however, not the only way in which the problem of thermometry at high temperatures may be attacked. Another method, and one that is more satisfactory in some ways because it is more fundamental, is to investigate the dependence of the energy upon the density of the gas. As pointed out at the commencement of this Report, any interdependence between energy and density at a given temperature must be accompanied by a corresponding deviation from the perfect gas-law, and investigation of change of energy with density must be the ultimate basis of gas thermometry. The Joule-Thomson experiment was, of course, of this character. Since then Joly has determined the change of specific heat of CO_2 at pressures ranging up to the critical pressure. But these determinations refer only to temperatures of the order of 100° C. As was pointed out at the commencement of the section of this Report dealing with explosions, the corresponding measurement at very high temperatures can be very easily made when once the various corrections necessary to determine internal energy by explosion experiments have been satisfactorily performed. It is only necessary to compare the pressures reached in explosions of mixtures identical in composition but of different density. Should the pressures after explosion, when corrected, be proportional to the pressures before explosion, then the energy is independent of the density, and we have proof that the gas-law holds up to the temperature reached by the combustion. On the other hand, a departure from the proportionality would imply a corresponding departure from the gas-laws, the amount of which could be calculated. Mallard, Le Chatelier, and Langen have made very careful comparisons of this kind, and they have found that the actual maximum pressures reached in the explosions are in many cases very approximately proportional to the pressures before explosion. Petavel has found that this proportionality is not much altered even when the density of the gas is increased seventy times. This may be regarded to some extent as evidence that there is no very great difference between the gas scale and the thermodynamic scale at the temperatures of 1700°, or more, which were reached in these experiments. But it must be observed that this inference is subject to the same limitations as the determinations of internal energy based upon these experiments. It cannot be regarded as having a secure foundation until the various doubtful questions in regard to heat loss and delayed combustion, which have been raised above in this connection, have been satisfactorily determined.

The Committee think that they can usefully continue their work in the direction of suggesting, and to some extent organising, research on the lines which have been foreshadowed in this Report. Research of this kind is expensive, and the Committee are of opinion that their work would be greatly facilitated if they had some funds at their command. They therefore recommend that they be reappointed, and ask for a grant of 100*l.*

APPENDIX.

The Deviation of Actual Gases from the Ideal State, and on Experimental Errors in the Determination of their Specific Heats. By Professor H. L. Callendar, *M.A., LL.D., F.R.S.*

1. The equation $pv = R\theta$, where θ is absolute temperature, is the characteristic equation of a fluid which (1) obeys Boyle's Law at all temperatures, and (2) has the difference of its specific heats constant and equal to R. The specific heat at constant volume or pressure may vary in any manner with temperature, provided that the difference of the two is constant; but both specific heats must be independent of the pressure or density.

For the majority of common gases or vapours (excluding those which polymerise, like sulphur) the deviations from Boyle's Law, as measured by the defect $(R\theta/p - v)$ of the actual volume from the ideal volume, at moderate pressures (say up to ten atmospheres) are to a first approximation a function of the temperature only, and diminish rapidly with rise of temperature. On this assumption tables of correction for the gas-thermometer have been independently calculated by Callendar [1] and D. Berthelot [2] for various gases when employed in the usual manner. The corrections are very small, and agree very closely, though calculated on slightly different assumptions. The differences are much too small to be taken into account in gas-engine experiments.

In dealing with a mixture of gases and vapours at high temperatures, the method of procedure is necessarily somewhat different from the case of the gas-thermometer, and the tabulated corrections do not apply. The effective temperature of the mixture is calculated from the value of the product pv/R, assuming that the composition of the mixture is known, and that the constant R has the same value per gramme molecule for each of the constituents as for an ideal gas. The errors involved in this method will be small, and will diminish with rise of temperature, provided that the constituents do not dissociate or polymerise. The experimental evidence at present available with regard to dissociation would indicate that the error of this assumption is certainly less than 1 per cent. for a gas-engine mixture at 2000° C., if the composition of the products of combustion is known.

[1] *Phil. Mag.*, January 1903. [2] *Trav. et Mém. Bur. Int.*, Paris, 1903.

Effective Temperature and Effective Specific Heat.

2. Since the temperature of a mass of gas, when exploded in a closed vessel or in the cylinder of a gas-engine is far from uniform, and since the actual distribution of temperature is necessarily somewhat uncertain, it is evident that the variation of the specific heats of the constituents with temperature cannot be *certainly* deduced from a knowledge of the heats of combustion and the effective temperature, even apart from difficulties inseparably connected with the determination of the cooling corrections. It is possible, however, by explosion experiments to deduce values of the *apparent* or *effective* specific heats which, in so far as they approximate to the conditions actually existing in the gas-engine, may be of greater practical utility than the true specific heats would be if they could be independently determined. The method of Dugald Clerk, in which the specific heat is directly determined from the work done on the charge after ignition, appears to be particularly appropriate for this purpose.

It is well known that the values of the specific heats deduced from explosion experiments are generally higher than those deduced by more direct methods, and it has been customary to explain the discrepancy largely by possible errors inherent in the explosion method. Such errors undoubtedly exist, and require careful investigation, but in arriving at a decision it is most important to subject other experimental methods to an equally close scrutiny.

Experimental Errors in the Determination of the Specific Heats of Gases by the Constant-pressure Method.

3. Apart from errors in the measurement of the temperature of the gas and of the calorimeter, which are not likely to be serious at low temperatures, there is an important source of error in this method, as applied by Regnault and subsequent observers, which has generally been overlooked. In Regnault's experiments, the rate of gain of heat from the heating vessel by the calorimeter was observed before and after the experiment proper, while the gas was not passing through the connecting tube, and was assumed to be the same whether the gas was passing or not. The correction amounted, when the heater was at 200° C., to between 4 per cent. and 5 per cent. of the heat supplied by the gas.

The effect of the gas current would certainly be to change the temperature gradient in the connecting tube in such a manner as to diminish the heat conducted from the heater during the passage of the gas. The error from this cause cannot be exactly determined, but would probably amount to between 2 per cent. and 3 per cent. in Regnault's experiments at 200° C., and would have the effect of making the values as determined by Regnault too low. The true variation of the specific heat of water was unknown in Regnault's time, and he was also unable to correct his thermometers accurately to the absolute scale. These considerations introduce minor uncertainties which might amount to as much as 1 per cent. on the result.

The specific heat of air considered as a mixture of perfect diatomic gases, taking the calorie at 20° C. as equivalent to 4·180 joules, should be 0·2405. Since air is not a perfect gas the actual value must be somewhat greater than this. Regnault's value, 0·2375, is evidently too low.

E. Wiedemann obtained the value 0·2389 by a method similar to Regnault's. This value is probably affected by a similar error.

J. Joly measured the mean specific heat of air at constant volume, and at densities 7 to 22 times normal, by the method of the steam calorimeter, between 10° and 100° C. This method has the advantage of avoiding the majority of the sources of error above mentioned. Joly's value for air at constant volume when reduced to the calorie at 20° C. and to normal density, would be 0·1732, which corresponds to a value 0·2419 for the specific heat at constant pressure at a temperature of 55° C.[1] This is a far more probable value than Regnault's, but it must be observed that the extrapolation of the experiments to atmospheric pressure involves some uncertainty.

The specific heats of air and CO_2 at atmospheric pressure and at temperatures of 20° and 100° C. have recently been determined by Swann at the Royal College of Science by the continuous electric method previously employed by Callendar[2] in the case of steam. In this method the actual specific heat at any point is determined by observing the rise of temperature produced in a steady current of gas at the required temperature by supplying a measured quantity of electric energy. This method is better adapted than Regnault's for determining the variation of the specific heat, because it gives the actual specific heat over a small range (about 5°) at the required point in place of the mean specific heat over a large range. It has also the advantage that systematic errors may be more completely eliminated.

The values obtained by Swann for the specific heat of air at atmospheric pressure in terms of the calorie at 20° C. equivalent to 4·180 joules were:—

$$S=0{\cdot}2415 \text{ at } 20^\circ \text{ C., and } S=0{\cdot}2425 \text{ at } 100^\circ \text{ C.}$$

His value at 55° C. is in very good agreement with that deduced above from Joly's experiments by the constant-volume method. Adopting a linear formula, we have for the specific heat at any temperature, t, between 0° and 100° C.

$$S_t=0{\cdot}2413(1+0{\cdot}00005t) \text{ (Swann).}$$

Holborn and Austin[3] and Holborn and Henning[4] extended Regnault's method for the determination of the mean specific heat to temperatures up to 840° C. In working at these high temperatures the difficulties of the method are greatly increased. They found it necessary to employ electric heating and to connect the heater to the calorimeter by a porcelain tube in order to diminish conduction. The temperature of the hot gas was observed with a thermo-couple near the entrance to the calorimeter. The time of flow was about three minutes in each experiment, and the corrections were estimated by observing the rate of change of temperature of the calorimeter before and after each observation. There appeared to be some doubt whether the couple would give the true mean temperature of the gas-flow, especially as the time of flow was so short. For this and other reasons the authors do not lay great stress on the

[1] Callendar, *Phil. Mag.*, January 1903, p. 76.
[2] *Proc. R.S.*, 1900.
[3] *Sitz. Akad. Wiss.*, Berlin, 1905, p. 175.
[4] *Wied. Ann.*, **18**, 1905, p. 739.

accuracy of the absolute values of the specific heats obtained, but consider that the ratios or relative values, and the rates of increase with temperature, are more likely to be correct than the absolute values, because the various sources of error which they discuss are more likely to be eliminated in the relative values.

The value found for the mean specific heat of air over the range 115° to 270° C. by Holborn and Henning was ·2315, which is about 5 per cent. smaller than the probable value over this range. For the rate of increase of the mean specific heat they gave the formula :

$$S_{o,t}=S_o(1+\cdot 00004t) \text{ (Holborn and Austin).}$$

but considered that the rate of increase shown by their experiments was within the limits of probable accuracy of their work, and that it could not be regarded as certainly established that there was any increase over the range of their experiments.

Later experiments by Holborn and Henning[1] with a platinum heating tube, extending to 1400° C., were made by a similar method, except that the gain of heat by the calorimeter from the heating tube was partly compensated by surrounding the calorimeter at 115° C. with a jacket maintained at a much lower temperature. This compensation was found necessary at high temperatures in order to prevent an excessively rapid rise of temperature of the calorimeter ; but although it reduces the apparent magnitude of the correction for gain of heat by the calorimeter, it does not diminish the actual amount of heat transferred and does not reduce the uncertainty of the correction. The magnitude of the effect at high temperatures may be judged from the fact that it was found necessary in the experiments at 1400° C. to maintain the jacket at as low a temperature as 40° C. by passing a stream of cooling water through it in order to prevent the calorimeter rising above 115° C. when no gas was passing. Under such conditions the calorimetric corrections become so uncertain that the probability of systematic errors must increase considerably with rise of temperature. If the method gives a probable error of 5 per cent. in defect over the range 115° to 270° C. it does not seem at all impossible that the error may amount to 10 per cent. over the range 115° to 1400° C.

The rate of increase of the mean specific heat of nitrogen at atmospheric pressure between 840° and 1340° C., shown by the later experiments, was about double that found in the earlier series. Both series of experiments could be represented within the limits of probable error by the linear formula

$$S_{o,t}=\cdot 2350(1+\cdot 00008t) \text{ (Holborn and Henning).}$$

It appears probable, however, that the value of the specific heat at 0° C. given by the formula is too low, and that the rate of increase is not uniform, but increases with rise of temperature to some extent in the case of nitrogen.

Specific Heat of CO_2.

4. Similar remarks apply to the determination of the specific heat of CO_2 by the same methods, but the case of CO_2 is of special interest on account of the rapid variation observed at ordinary temperatures. The

[1] *Wied. Ann.*, **23**, 1907, p. 809.

following table gives the specific heats of CO_2 according to different observers at 0° and 100° C. :—

Temperature	Regnault	Wiedemann	Swann	Holborn
0°	0·1870	0·1952	0·1973	0·2028
100°	0 2145	0·2169	0·2213	0·2161
Increase . .	0·0275	0·0217	0·0240	0·0133

The value of the mean specific heat at constant pressure from 10° to 100° C. deduced from Joly's experiments at constant volume is 0·2120, which is nearly 5 per cent. higher than Regnault's value at this temperature, but agrees as closely as can be expected with that found by Swann. The variation of the specific heat with density observed by Joly agrees very closely with that calculated by Callendar [1] from the experiments of Joule and Thomson on the cooling effect in expansion through a porous plug.

The rate of increase of the specific heat between 20° and 100° C. observed by Swann is nearly a mean between the rates given by Regnault and Wiedemann, but is much larger than that found by Holborn and Henning, or deduced by Langen from explosion experiments. It is probable that the variation is not linear, but that the rate of increase diminishes with rise of temperature, as indicated by Mallard and Le Chatelier's formula, which would make the specific heat a maximum at 1700° C. The latter formula differs from Holborn and Austin's by more than 20 per cent. at 800° C. The explanation appears to be partly that Regnault's value for the rate of increase at 100° C., adopted by Mallard and Le Chatelier, is too high, but chiefly that Holborn and Austin's values, as already explained in the case of air, are systematically too low, and that the error increases with rise of temperature.

Specific Heat of Steam.

5. Regnault's value 0·475 for the specific heat of steam at atmospheric pressure over the range 125° to 225° C. was obtained by taking the difference between the total heats of steam, superheated to these temperatures, as observed by condensing the steam in a calorimeter. Since the difference, corresponding to 100° superheat, is only $\frac{1}{14}$th of the total heat measured in either case, it is evident that the method might give rise to large errors. For this reason many writers have preferred to deduce the specific heat of steam theoretically in various ways from Regnault's value of the rate of change of the total heat of saturated steam, namely, 305 cal. per 1° C., which, however, really involves the same source of error in an aggravated form. Thus Zeuner gives $S = 0·568$; Perry,[2] $S = 0·306$ at 0° C. to 0·464 at 210° C. ; Grindley [3] 0·387 at 100° C. to 0·665 at 160° C.

A direct measurement of the specific heat of steam by the continuous electric method gave $S = 0·497$ at 108° C.[4] Subsidiary experiments, in conjunction with Professor Nicolson,[5] by the throttling calorimeter method

[1] *Phil. Mag.*, January 1903, p. 78.
[2] *Steam Engine*, 1899, p. 582.
[3] *Phil. Trans.*, 1898.
[4] Callendar, *Proc. R.S.*, 1900.
[5] McGill College, 1897.

enabled the variation of the specific heat with pressure to be calculated. These gave the formula

$$S_t = 0\cdot478 + 0\cdot0242\ p\ (373/\theta)^{4\cdot3} \quad \text{(Callendar)}$$

where p is the pressure in atmospheres. The approximate constancy of the limiting value 0·478 of the specific heat at zero pressure over the range 0° to 200° C. was verified by calculating the corresponding values of the saturation pressure, which were found to agree accurately with Regnault's observations over the whole range. The theory was also verified by a measurement of the ratio of the specific heats of steam by Makower,[1] which gave values 1·303 to 1·307, agreeing closely with that deduced by Callendar.

The experiments of Lorenz,[2] and of Knoblauch and Jacob and Linde[3] afforded a remarkable verification of the theory of the variation of the specific heat with pressure. They found the specific heat at 1 atmo. to be practically constant over the range 100° to 300° C., but their value, namely, 0·463, is decidedly lower than Regnault's.

Holborn and Henning,[4] in their experiments on the specific heat of steam at atmospheric pressure, improved Regnault's method by employing an oil calorimeter at 110° C. so as to avoid condensing the steam in the calorimeter. They determined the ratio of the specific heat of steam to that of air by passing currents of air and steam in succession through the apparatus under similar conditions, and obtained the following values of the ratio for different intervals of temperature :—

Temperature Interval .	110°–270°	110°–440°	110°–620°	110°–820°
Ratio/Steam : Air . .	1·940	1·958	1·946	1·998

In their subsequent series with a platinum heating-tube at higher temperatures they obtained the following ratios :—

Temperature Interval .	115°–826°	115°–1180°	115°–1324°
Ratio/Steam : Air . .	1·900	1·973	2·003

The second series appears to make the ratio about 5 per cent. lower at 110°–820° than the first, wh ch suggests the possibility of constant errors depending on the type of apparatus employed or on the velocity of the gas-current. The experiments of Callendar and Swann would make the ratio 2·05 at 100° C., which is higher than any of the values obtained by Holborn and Henning at 1400° C.

Holborn and Henning point out that their results at 1400° C. cannot be reconciled in the case of steam and CO_2 with any of the results of explosion methods. They are 6 per cent. to 13 per cent. lower than Langen's, which are among the lowest. But having regard to the fact that the constant-pressure method which they employed appears to give results so much lower than Joly's or Callendar's methods at ordinary temperatures, and that the experimental difficulties increase so greatly at higher temperatures, it does not seem at all improbable that a considerable part of the discrepancy is to be attributed to systematic errors of the constant-pressure method.

[1] *Phil. Mag.*, February 1903.
[2] *Forsch. Ver. Deut. Ing.*, 21, 1905, p. 93.
[3] *Loc. cit.*, pp. 1 and 35, 1906, p. 109.
[4] *Ann. Phys.* xviii. 1905, p. 739.

On the Cause of the Variation of Specific Heat.

6. It appears from theory that the energy of translation and rotation of the molecules of an ideal gas should vary in direct proportion to the product *pv*. The internal energy of vibration of the molecules, however, which is related to the absorption or emission of radiation must vary by the Stokes-Kirchhoff law in relation to the full radiation of a black body at the same temperature. According to Planck's formula, which has been verified over a very wide range, the energy of full radiation corresponding to wave-length L in full radiation, varies with the temperature according to the expression

$$\underset{L}{E}=CL^{-5}(e^{c/L\theta}-1)^{-1}$$

the value of the constant c is 14,700 if L is measured in microns, μ, or millionths of a meter. The energy of vibration of a molecule which is in equilibrium with full radiation at any temperature will depend on the extent to which its free periods of vibration respond, as indicated qualitatively by its absorption spectrum. Those periods which respond very strongly may produce an appreciable effect on the specific heat.

It happens, for instance, that CO_2 has a very marked absorption band at 15μ, nearly, which can be detected even when the gas is present in small quantities in the atmosphere. So far as this particular mode of vibration is concerned, the specific heat would increase most rapidly at ordinary temperatures, which is actually observed to be the case with CO_2. According to Planck's formula, the effect of any mode of vibration would be a maximum when θ is infinite, and would then contribute the term C/cL^4 to the mean specific heat; but for $L=15\mu$ the effect would have already reached within about 10 per cent. of the possible maximum at 2000°. According to Wien's original formula

$$\underset{L}{E}=CL^{-5}e^{-c/L\theta}$$

which holds very well for short wave-lengths and low temperatures, but appears to fail when $L\theta$ is large, the energy E would reach a finite limit CL^{-5} when θ is infinite, and the specific heat for $L=15\mu$ would reach a maximum when $\theta=500°$. This does not appear to agree so well with the changes of specific heat actually observed.

In the case of steam it appears that there are no equally well-marked absorption bands corresponding to strong natural periods of vibration, in the range of the heat spectrum available for investigation. The very high dielectric constant of water for short electric waves has been taken to indicate that there is a period of marked resonance very low down in the spectrum in the unexplored field between the shortest electric waves and the longest heat waves hitherto obtainable. This might account for the relatively high value of the specific heat of water and steam at ordinary temperatures. It must be remembered, however, that the absorption spectrum is very complicated and difficult to investigate beyond the limits of photography. Moreover, it is very difficult to deduce, except in a qualitative manner, the relative intensities of the energy corresponding to each absorption band. An absorption band may appear strongly marked in a thick layer of absorbent, which really corresponds to a very small amount of energy. For this reason no quantitative estimation of the effects of vibration of the molecules on the specific heat is possible at the present stage of knowledge, but it is important to bear the possibility of such effects in mind as a guide for future investigation.

Megalithic Remains in the British Isles.—Report of the Committee, consisting of Professor W. RIDGEWAY (*Chairman*), Dr. G. A. AUDEN (*Secretary*), Dr. H. A. AUDEN, Mr. G. L. GOMME, Professor J. L. MYRES, *and* Mr. F. W. RUDLER, *appointed to report on the best means of registering and classifying systematically Megalithic Remains in the British Isles.*

THE Committee was appointed at the York Meeting (1906) of the Association, and made an interim report at the Leicester Meeting (Report Brit. Assoc., Leicester, 1907, p. 391). The present report brings the work of the Committee to an end.

The Committee's first task was to inquire what means are adopted in other countries for the registration and classification of megalithic monuments. In this task the Committee has received valuable assistance from foreign scholars, and particularly from Dr. Oscar Montelius, Dr. Sophus Müller, Herr Haakon Schetelig, and M. Salomon Reinach. To these distinguished colleagues the Committee desires to express its most hearty thanks.

The Committee desires to point out, in the first place, that in regard to Scotland and to Wales its task has been greatly simplified by the recent appointment of official Commissions to report upon the historical monuments of those countries. For it is obviously within the scope of those Commissions to register and classify megalithic remains; and all future investigations by individual observers or by local organisations should be carried out in co-operation with these Commissions.

Neither England nor Ireland is as yet provided with an official Commission of this kind; and the Committee strongly urges that the British Association should use its influence vigorously and promptly to secure the creation of such Commissions at the earliest opportunity. Every year's delay means damage or dangerous neglect of one or more of these monuments and the loss of some part of those local traditions concerning them which are so valuable an element in our knowledge. Pending the appointment of such official Commissions for England and for Ireland, the Committee desires to indicate briefly the means which exist already for registration and classification such as is contemplated.

The Ordnance Survey has devoted considerable attention to the record of all early remains and of megalithic monuments among the rest, and possesses much valuable material for more detailed description and registration. The Committee recommends that local observers should put themselves in communication with the Ordnance Survey in the event of the discovery of new monuments or of new evidence as to existing monuments.

The 'Victoria County Histories,' now in course of publication, are providing in the case of England (though not for Ireland) a very systematic survey and register of all ancient remains, and also the outlines of a classification of them. The Committee recommends that local observers should put themselves in communication with the editors of these 'Histories' (2 Orange Street, Leicester Square, W.C.), with the object of making this record complete and of reducing the risk of overlap and duplication. The Committee submits this recommendation more particularly to the consideration of the Conference of Delegates of Corresponding Societies.

Finally the Committee desires to impress upon the British Association the serious risk to megalithic monuments which results from the present inadequate provisions and ineffective working of the Ancient Monuments Act. The registration and classification of megalithic monuments falls clearly within the proper province of an official inspector of ancient monuments; and in other countries, which value their monuments, the work in question usually forms one of the duties of such an inspector.

Notes and Queries in Anthropology.—Interim Report of the Committee, consisting of Mr. C. H. READ (*Chairman*), Professor J. L. MYRES (*Secretary*), Professor D. J. CUNNINGHAM, Mr. E. N. FALLAIZE, Dr. A. C. HADDON, Mr. T. A. JOYCE, Dr. C. S. MYERS, *and* Dr. W. H. R. RIVERS, *appointed to prepare a new edition of Notes and Queries in Anthropology.*

THE work of revision, of which an outline was given in last year's report, has been continued; but it has not yet been thought desirable to begin the reprinting. The Committee, therefore, has incurred no expenditure, and wishes to be reappointed, with renewal of the original grant.

Excavations on Roman Sites in Britain.—Report of the Committee, consisting of Professor J. L. MYRES (*Chairman*), Professor R. C. BOSANQUET (*Secretary*), Sir EDWARD BRABROOK, Dr. T. ASHBY, Mr. D. G. HOGARTH, *and* Professor W. RIDGEWAY, *appointed to co-operate with Local Committees in Excavations on Roman Sites in Britain.*

THE Committee has made grants of 5*l.* in each case in aid of excavations on Roman sites at Caerwent, at Corbridge, and at Gelligaer, near Cardiff. In each case the grant has been made on the same conditions as in former years; namely, that it should be applied to carry out special investigations in regard either to pre-Roman remains found in the course of the excavations already in progress, or to non-Roman objects such as plant and animal remains, which might otherwise have been put on one side. The Appendices A and B show the mode in which the grants made by the Committee have been expended at Caerwent and at Corbridge respectively. The work at Gelligaer has not gone far enough to be included in the present report, but a summary of it will be submitted in due course.

The Committee asks to be reappointed with a further grant.

APPENDIX A.

Report on Plant Remains found in Excavations on the Roman Site at Caerwent, 1907. *By* ARTHUR H. LYELL.

The specimens of soil from wells and drains were practically devoid of seeds, only a very few specimens existing in a large bulk of material examined, and of these there is unfortunately nothing new to report.

A few fragments of bone and insects were also found, the former of which have been identified by Mr. E. T. Newton, and are given below.

Plant Remains.

House V.—Well T (82).

Elder	(*Sambucus nigra*).
White Goosefoot	(*Chenopodium album*).
	(*Polygonum*).
Dock	(*Rumex Acetosa ?*).

House VN.—From bottom of Well T (84).

White Goosefoot	(*Chenopodium album*).
Dock	(*Rumex crispus ?*).
Nettle	(*Urtica dioica*).

Top of Drain under wall of House XVI.
Grain of Wheat (*Triticum*).

Bones.

House VN.—Box Drain S. end T (93).
Roebuck phalange.
Vole tooth.
Bird fragment.
Blindworm vertebra.

Top of Drain under wall of House XVI
Vole.
Shrew.
Blindworm.
Fish fragments.

APPENDIX B.

Report of Work on Pre-Roman and Natural History Remains at Corbridge, 1907–08.

A. *Pre-Roman Remains.*—It has often been maintained that a pre-Roman settlement existed at Corbridge, and Henry MacLauchlan [1] held that such a settlement would explain the fact that the Roman road from the south descends into the Tyne valley near Riding Mill, but does not at once cross the Tyne; instead it follows the south bank for two miles till opposite the site of Corstopitum. Accordingly a careful search was made for prehistoric objects, and in particular a large trench, 80 feet long, 5 feet wide, and in general 11 or 12 feet deep, was dug across the lower part of the portion of the site under examination, under the

[1] *Memoir written during a Survey of the Roman Wall in* 1852–4 (London 1858).

superintendence of Mr. C. L. Woolley. This spot when first tested seemed to offer signs of an old inhabited surface below and previous to the Roman occupation. But the complete trenching showed that the appearance was deceptive or at least insufficient to prove any definite settlement. Between the lowest Roman deposit and the wholly untouched soil were two strata—two at the north or upper end of the long trench and one at the south end near the river. The upper stratum was 3 inches thick at its north end, and there consisted of black or burnt matter. Further south it was composed of sandy clay, through which the stems of plants and reeds ran perpendicularly. The lower stratum was a thin layer of the same sandy clay containing a number of small flint chippings. The upper part of the untouched soil beneath this layer was full of the root-fibres of grass, &c., carbonised or decayed black. A few rough flint-flakes and scrapers also occurred loose in the upper soil on other parts of the site, and one or two were picked up in the excavations of 1906.

B. *Bones.*—Many specimens of bones were submitted to Professor A. Meek. He reports the following :—Dog, pig, sheep, red deer, pony, cattle (including a calf), fox, badger, roe deer, swan, pheasant (13 feet deep), lower jaw of European beaver, partridge, grouse, oyster-shells from the sea, shell of mytilus (marine mussel), and many snail-shells found between two concrete floors, *Helix aspersa* (many), *nemoralis* (a few), *hortensis* (a few), and *rotundata* (one), all now common at Corbridge. These snails *may*, of course, be of recent origin. Professor Meek observes that the *Bos longifrons* was represented by a great variety of sizes ; the majority were about the size of the present Chillingham cattle ; but some were as large as our shorthorns, while one skull indicates a small, possibly wild, variety allied to the Chillinghams. One or two jaws had the absence of the first premolar which characterises the Chillingham.

C. *Geology.*—Various sections were examined by Professor Lebour, and his explanations considerably aided the work; but no results of a new geological kind emerged.

Archæological and Ethnographical Researches in Crete.—Report of the Committee, consisting of Sir JOHN EVANS (*Chairman*), Professor J. L. MYRES (*Secretary*), Professor R. C. BOSANQUET, Dr. A. J. EVANS, Mr. D. G. HOGARTH, Professor A. MACALISTER, *and* Professor W. RIDGEWAY.

THE Committee was reappointed in 1907 without grant ; but it has been in communication with Mr. C. H. Hawes, whose valuable researches on the physical characters of the population of Crete were reported in 1903,[1] with the object of inducing him to make another expedition to Crete. There is now every reason to believe that, if a sufficient grant be forthcoming, Mr. Hawes will be in a position to carry out this plan, and complete his investigation under the most favourable conditions.

[1] *Proc. Brit. Assoc.*, 1905, South Africa, p. 208.

An interim report from Mr. Hawes is appended :—

In 1905, at the request of the Cretan Committee of the British Association for the Advancement of Science, I went to Crete to follow up Dr. Duckworth's investigations of the physical characters of the ancient and modern Cretans.[1]

Four months spent in the island enabled me to travel from village to village throughout the length and breadth, thus avoiding the plan often imposed on the anthropologist from want of time, of culling his data from police, prison or other institution.

In the first place I excavated at Palaikastro, and later made occasional trial 'digs' *en route.* At Candia I examined some skulls discovered since Dr. Duckworth's visit, and the rest of the time was spent by me in journeying to and fro in the island.

In excavating at Palaikastro I came upon several interments of about the Third Late Minoan period in 'larnakes,' but the majority of the crania in them were too much crushed by the fallen earth to be accurately measured. Those that could be determined, together with other skulls found since Dr. Duckworth's inspection, at Knossos, Aghia Triadha, Konmasa, and near Gournia, and measured by me in the Museum at Candia, amount to eleven only.

Of these eleven, four belong to the same Early and Middle Minoan periods as those measured by Dr. Duckworth ; one is dolichocephalic, one is brachycephalic, and two are mesocephalic. Of the other seven belonging to the Third Late Minoan, three are mesocephalic and four are brachycephalic.

These skulls are, of course, too few to base any theory upon, yet it is significant that the large proportion of brachycephalism at the close of the Bronze Age tallies with archæological evidence as to an invasion of peoples from the north ; and while Dr. Duckworth's figures go far to prove the affinity of the Early and Middle Minoans with the Mediterranean race, he would be the first to admit the importance of the brachycephalic element which we have seen to be present even in these early times.

Any attempt to determine the origin of these broad heads must be as yet in the nature of a guess. From Africa at this early period we expect only long heads ; from Italy, the Greek mainland, and the coast regions of Asia Minor a similar race. There remain the Transbalkan area and the uplands of Asia Minor.

The Anatolian highlands were inhabited at this period by the so-called Hittites, who from ancient skulls and traces in the modern population have been classed by von Luschan as brachycephalic. On the other hand, it may be that the Alpine race on its westward journey from Irania to Central Europe sent a few stragglers southwards, either direct from Asia Minor to Crete, or *via* the Bosphorus and Thessaly. Organised such offshoots of the Alpine race may have been, but judging from the condition of their kinsmen who built the *early* Lake Dwellings of Switzerland, they must have been a primitive folk, yet in the Neolithic stage, unable to make much impress on the higher civilisation then existing in Crete, especially since they were few in numbers. For, whether Hittites or members of the Alpine race, we are concerned with slight infiltrations

[1] *Proc. Brit. Assoc.*, 1903, Southport, p. 404.

only, probably of a peaceful character. It might be possible, with more crania, to decide between the two, for the Hittites had probably a greater admixture of 'Armenoid' skulls than the Alpine, and the characteristic verticality of the occiput might solve the problem. I can only say that to-day the Armenoid type is found, especially in the east end of the island.

In my work of measuring modern Cretans, I planned to get a representative collection of records from each eparkhy, and fuller ones from such as Sphakia, which had special attractions. In each of these political divisions I gathered my data from highland and lowland, mountain and plain; I failed, however, to traverse the eparkhies of Kissamos and Selino, although I obtained records of sixty-nine persons hailing from them. On the borders of Kydhonia and Sphakia I had been attacked in a lonely mountain pass, and although this did not prevent the continuation of my work, the situation was more difficult in the two neighbouring eparkhies, which were then witnessing a struggle between the insurgents and the international troops.

In the great majority of cases I measured the maximum head length and breadth, stature, nasal length and breadth, maximum circumference of head, facial length and breadth, nasal-, alveolar-, and altitudinar-radii, and the inter-ocular breadth. I recorded the colour and character of the hair, complexion, colour of eyes, shape of face, prominence of cheek-bones and jaws, flatness of ears and presence of lobes, together with full genealogical data.

In all about 29,000 observations and measurements were made upon 1440 persons. Although tact was required, the work of getting people to be measured was not so difficult as it might seem. On the other hand, it was almost out of the question to persuade women to be the subjects of one's inquiries and it was not an easy matter to overcome the shyness of Mussulmans. The records include 24 only of the former and 124 of the latter.

In the following statements I have included, where possible, Dr. Duckworth's records with my own :—

The average breadth or cephalic index for 1600 modern Cretans (♂) is 79·2, and stature for 1563 is 1686 mm. These are the two available characters of the 62 (♂) ancient skulls of the Early and Middle Minoan period and a comparison as follows :—

Modern .	Breadth index 79·2 corrected to cranial index (79·2 − 2·0)	= 77·2
Ancient .	Cranial index	= 73·4
Modern .	Stature	1686 mm.
Ancient .	„ (estimated)	1625 „

shows a broadening of the cranium and an increase of stature.

This brachycephalic tendency began early in the Bronze Age, if not indeed in the Neolithic Age, but in the figures at our disposal only amounted to $8\frac{1}{2}$ per cent. of the whole. Judging from the scanty material the minority of broad heads was unimportant until the end of the Bronze period.

This broadening tendency seems to have continued into modern times. To what are we to attribute it? To dismiss two possible theories, I do not credit this result to either artificial selection or civilisation. If anywhere, sexual selection might have been expected to have played its part in producing those Cretans most noted for their beauty, the inhabitants of the mountain villages of Anogeia and Lakkoi, the refuges of the finest and fairest of their womenfolk from the grasp of the Turk. Yet at Lakkoi I found the breadth index nearly two units (77·4) below the general average for Crete.

Nor can we fairly assume, as Bogdanov did for Russia, that this broadening of the crania is due to civilisation, for Crete has only just begun to be re-civilised, and methods of travel, for instance, are what they were 1000 or 2000 years ago.

Immigration, in my opinion, have been responsible for the increasing brachycephalic element.

The first serious contribution may have been at the end of the Bronze Age. The Sphakiotes, who claim to be descended from the Dorians and are certainly purer blooded than the rest of Crete, have broader heads (80·1) than the Cretan average (79·2).

We may pass over the Saracenic invasion, not because its members must have resembled the natives so closely as to leave little trace, but since history encourages the belief that few were left after the Byzantine conquest.

It is different with the Venetian occupation, and I sought in many directions for traces of this element in the broadening of the head and the raising of the stature of the modern Cretan. The French historian, Jules Buillot, says that 'permission was given for mixed marriages (a practice unusual in Venetian colonies) which tended to make the Venetian colonists good Cretans and lukewarm Catholics.' On the other hand, their evacuation in the middle of the eighteenth century when the Turks captured the island, was complete, and whereas we find Venetian families in Corfu and the Ægean to-day, it is with difficulty that we can discover any in Crete. Three or four families, the Cornaros from Carpathos, the Moitso from Cythera, the Dandolo and Modatso families are met with in the chief cities, Candia, Canea, and Rethymo.

In my efforts to probe this question, I sought eagerly for any names in villages which boasted of Venetian remains, and in some of these I had whole lists of the heads of families taken down. Among these Dr. Jannaris, whom I met at Lakkoi, could recognise none but Cretan names, with the exception of Venetakis, which he dubbed a nickname given to the native servant of a Venetian. When measuring in the Insurgents' Camp I came upon two men who claimed to be of Venetian descent one named Markandonakis (Mark Antonio) and the other Reneris (Renero). Their breadth indices were diverse, respectively 78·5 and 87·3, but the latter from a consideration of all his measurements, &c., might have passed for a Venetian.

Several difficulties face the anthropologist in attempting to discover the Venetian element which, on the whole, I believe, exists in the Cretan to a small extent. The Venetians did not occupy any one portion of the island to the exclusion of any other. Therefore any physical modification is lost to sight in being spread over the whole island. They are themselves a mixture probably of Alpine and Illyrian stock with the native, and in height and breadth index are not to be distinguished from the Turk. Yet I do not despair of being able to separate these elements after a close and exhaustive analytical study of figures and records.

The last immigration, the Turkish, seems to me of more importance in our problem. 'If,' as Mr. Stillman, U.S. Consul in the sixties of last century, wrote: 'Everything was at the mercy of the Turk, the Cretan women included,' the Turkish soldiery must have been responsible for some race mixture. The Mussulman population amounted at one time to at least one-third of the whole, and in 1881 was certainly more than one-quarter. But these people, though generally called 'Turki' on the island, are not all Turk by provenance, for the great majority are of native Cretan descent.

Unfortunately their names give us no clue, and individuals can rarely give any information as to their forbears beyond the second generation.

The Turk of Asia Minor (though he still remains brachycephalic) is himself a great mixture, and the problem becomes further involved when we attempt to discriminate between half-breed descendants of Turks and Cretan women and Moslems of pure Cretan blood. What we should expect, however, is a higher cephalic index among the Mussulmans than among the Christians, and this my figures show.

The average breadth index of 124 Mussulmans is 79·9, and that of the Christians from the same eparkhies 78·9. Taking the eparkhies in which the largest number of Mussulmans were measured, the differences exceed one unit—*e.g.*, 1·8, 1·4, 1·6, and 1·5.

Two Cretan villages bear Slavic names, Sklavopoulos and Vulgaros, but a list of the names of the inhabitants of the former contains no trace of Slav nomenclature.

Turning to the other observed difference between the ancient and modern Cretans, to what are we to attribute the increase in stature? It is dangerous to build anthropological conclusions on differences in stature. They are often due to differences in fertility of soil or social condition. The archæological evidence, however, tells in favour of better conditions in the Bronze Age rather than the reverse. The effect of fertility is probably seen in the relatively higher stature in the well-watered west of the island. The reverse is best illustrated in the case of the arid island of Gavdos, whose people are descended from Sphakiotes, yet whose mean stature compares as 1632 mm. to 1713 mm.

Yet Sphakia is only rather better off as to its soil than Gavdos, and some other explanation must be found for the Sphakiote stature (194 persons), second to one only in the island, since theirs is a sterile soil, largely composed of a steeply descending talus on which beats a fierce Southern sun.

Can it be that their ancestors, the 'Dorians,' were tall? Across the border of the 8000-feet range of the White Mountains another puzzle awaits us.

Here we have the greatest mean stature in Crete (166 persons), 1720 mm., and it is greater in the mountains than in the plains; for of 150 individuals 79 who live above an altitude of 1000 feet have an average stature of 1737 mm., whereas 71 living below 1000 feet are only 1702 mm. in height. The difference in the breadth index is also well marked; for the mountaineers it is 77·4 and the lowlanders 80·3. We have no traditions of special 'Dorian' influence, and the cephalic index does not favour it; but from time immemorial the Lakkiotes, who form the majority of these 79 mountaineers, have been noted for their beauty, stature, and courage. It was among them, and especially their neighbours in Selino, that I met quite an appreciable number of auburn or fair-haired and blue-eyed persons. They seem to be the Scotch of the island in this respect and in point of stature. They differ from the Sphakiotes, among whom was no noticeable percentage of blondes. Also the contrast extends to character. The Sphakiote is dignified, intelligent, but given to ruses, even to treachery. The Lakkiote is kindly, open-natured, and brave.

I find, therefore, at present, the relatively great stature and low cephalic index of the Kydhonian mountaineers difficult to account for. There are, however, historical considerations which help. Neither the Venetians nor the Turks ever got a hold upon the highlands, and once only (in 1866) did the latter succeed in attacking Lakkoi. May not the low index, 77·4, reflect the absence of admixture with these two peoples?

The increased stature may be due in some measure to the healthier climate. Perhaps the greater frequency of blondes may be attributed to the fact that the finest, fairest, and most beautiful women of the plains were sent away to the mountains to escape rape by the Turks; but would this and the tendency for the boldest, strongest, and most venturesome spirits in the frequent revolutions to retire to the mountains, there to hold out against the oppressor—would these account for the greater stature?

These and many other problems, if they are to yield a solution, must do so to a further study on the field and mathematical experiments with the records obtained.

Notes.

Several suggestions occur from a perusal of some of the records, and I jot them down as tentative.

The Cretans, though mixed, as I have suggested, are, as compared with other races, only moderately so.

The standard deviation for the whole of Crete (breadth index), 1600 persons is . . .	4 1
The standard deviation for all the eparkhies (head breadth) varies from	4·1 to 6·1

This last compares with the

Naqada series	5·75
Cairene ,, ...	8·02

As between eparkhies the results of a trial of the probable error of the means (head breadth) are interesting and puzzling, but may provide us, when other characters are tried, with a key or keys.

The differences between Upper and Lower Kydhonia are significant of heterogeneity. The same is true between Upper Kydhonia and Sphakia, and also between Sphakia and the rest of Crete.

There is no significant difference of race between Upper Kydhonia and the rest of Crete; nor is there, and this is puzzling, between Lower Kydhonia and Sphakia. Can it be that, as we are dealing only with head breadth, the Turkish and Venetian brachycephalism has done for Lower Kydhonia what the 'Dorian' has done for Sphakia?

These experiments suggest more trials, but they also demand more field work. Among the several questions I want more light on from the field are: What is the significance of the blonde element in the west of the island, particularly in Selino, which I have not yet entered? I wish to follow up the differences between highlanders and lowlanders more carefully in the middle and east end of the island; for Rethymo confirms Kydhonian differences.

The Armenoid element in the modern Cretan should be investigated, and any trace of the same sought for in the ancient skulls. I should visit the village Abadia, which is said to retain Saracenic descendants; also examine fully the collection of skulls of the last three hundred years at the monastery of Aghia Triadha on the Aknoteri peninsula. In addition, photographs of types are wanted. I should add largely to my Mussulman records and attempt to get data of the three or four old Venetian families.

Archæological and Ethnological Investigations in Sardinia.—Report of the Committee, consisting of Mr. D. G. HOGARTH (*Chairman*), Professor R. C. BOSANQUET (*Secretary*), Dr. T. ASHBY, Dr. W. L. H. DUCKWORTH, Professor J. L. MYRES, *and* Dr. F. C. SHRUBSALL.

DR. DUNCAN MACKENZIE was able to visit Sardinia on behalf of the British School at Rome last autumn, and spent nearly two months in the island; during the last three weeks he was joined by Dr. Thomas Ashby, Director of the School. His researches were mainly devoted to the study of the relation between the 'nuraghi' and the so-called 'tombs of the giants,' the latter consisting of long chambers—sometimes as much as 50 feet long, but only three or four feet broad and high—with a semicircular area, inclosed by upright slabs or by walling in front of them; and he was able to discover several cases in which the 'nuraghe' and the tomb seemed to be in such close relation to one another (the latter being placed on a mound in the neighbourhood of, and easily visible from, the former) as to make it clear that the former was the fortified habitation, and the latter the family tomb. This was still clearer in several instances where the 'nuraghe' itself dominated a group of smaller circular buildings, no doubt dwellings under the protection of the 'nuraghe,' and usually inclosed in a ring wall starting from it. Dr. Mackenzie gave an account of his researches at an open meeting of the British School held at Rome in February last. Both he and Dr. Ashby intend to return to Sardinia in October.

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, Professors J. L. MYRES *and* A. F. DIXON, Mr. E. N. FALLAIZE, Sir EDWARD BRABROOK, Mr. G. L. GOMME, Dr. F. C. SHRUBSALL, Professor G. D. THANE, Dr. W. MCDOUGALL, Professor M. E. SADLER, Major H. J. M. BUIST, Fleet-Surgeon G. T. COLLINGWOOD, *and* Dr. J. KERR.

THE following Sub-Committees have submitted reports on particular branches of anthropometry :—

1. An Anatomical Sub-Committee, consisting of the Chairman, the Secretary, Dr. F. C. Shrubsall (*Convener*), Dr. T. H. Bryce, Professor G. D. Thane, Dr. Waterston, Dr. W. L. H. Duckworth.

2. A Physiological Sub-Committee, consisting of the Chairman, the Secretary, Dr. W. McDougall (*Convener*), Dr. C. S. Myers, Dr. W. H. R. Rivers, Dr. W. D. Halliburton, Mr. A. F. Shand, Mr. W. H. Winch.

3. A Psychological Sub-Committee, consisting of the same members as the Physiological Sub-Committee.

4. A Sub-Committee on Environment, consisting of the Chairman, the Secretary, Sir Edward Brabrook (*Convener*), Dr. A. C. Haddon, Dr. Halliburton, Dr. McDougall, Dr. Shrubsall.

5. A Photographic Sub-Committee, consisting of the Chairman, the Secretary, Professor J. L. Myres (*Convener*), Dr. A. C. Haddon, Mr. G. L. Gomme, Dr. W. L. H. Duckworth, Mr. A. Abraham, Mr. H. S. Kingsford.

6. An Educational Sub-Committee, consisting of the Chairman, the Secretary, Mr. E. N. Fallaize (*Convener*), Professor M. E. Sadler, Mr. W. M. Heller, Mr. C. M. Stuart, Dr. F. C. Shrubsall, Dr. C. S. Myers, Dr. W. H. R. Rivers, Sir Edward Brabrook.

7. A Sub-Committee on Schedules, consisting of the Chairman, the Secretary, Dr. F. C. Shrubsall, Dr. J. Kerr.

This may be regarded as the final Report of the Anthropometric Committee. The Committee commenced its work in 1902 by instituting a preliminary inquiry into the state of anthropometry in the British Isles. As a result of this inquiry it was made clear that the objects in view could best be attained by drawing up a uniform and consistent method of anthropometric investigation. The Committee has therefore devoted itself for several years to the elaboration of a standard scheme, and the results of its labours have from time to time been published in its annual reports. The present Report sums up the whole of the previous work of the Committee and embodies some additions and amendments that have been considered desirable. It consists of three previous reports re-edited, with the additional work accomplished during the present year.

In one department the Committee considers that its scheme is still incomplete—namely, in the method which is suggested for the determination of psychological measurements. A considerable amount of excellent work has been done on this subject, and some tests made in schools promise that the method will be of great value; but the psychological sub-committee considers that further investigation, extending over several years, may be necessary before a thoroughly satisfactory method can be arrived at.

Under the circumstances it has been decided to recommend that the present Committee should not be reappointed, but that a new Committee, entitled 'A Committee to promote the installation of anthropometry in schools and elsewhere, and to establish a system of measuring mental characters,' be appointed.

In order to maintain continuity in the work it is recommended that the Chairman and Secretary of the present Committee should be on the new Committee, and that Sir Edward Brabrook, Dr. A. C. Haddon, Professor Arthur Thomson (Oxford), Dr. McDougall, Dr. Spearman (University College, London), and Miss Cooper (Delegacy for Training Secondary Teachers, St. John's, Oxford) should be appointed members. It is recommended that a grant of 5*l*. should be made to the new Committee.

THE OBJECTS OF ANTHROPOMETRY.

The objects of anthropometry are in the first place to measure as exactly as possible the structure and activities of the human body, and in the second place to measure the factors of the environment with which changes in man's structure and activities are associated. The structure of man is ascertained by measuring a sufficient number of his anatomical or bodily dimensions, and his activities or functions by measuring such physiological characters as vision, hearing, smell and tactile sensibility, and such mental characters as are considered to be of the greatest importance in human life.

As all these characters vary when subjected for a sufficiently long time to a changed environment it is important and essential to measure the principal factors of the environment of the men or groups of men we are studying. From the data obtained from such complete observations correlations between man and his environment can be ascertained, and we can thus determine certain of the laws of human evolution, which is the ultimate object of anthropometry. The knowledge of these laws is of the highest importance to rulers, statesmen, and all authorities interested in social reform. Such questions, for example, as that of physical deterioration, which has recently been the subject of official inquiry in this country, can only be satisfactorily dealt with by establishing periodic anthropometry as a national institution. In addition to these practical applications the results of anthropometric investigation will be of the greatest value to science by enabling us to obtain a clearer conception of many problems of the greatest interest to the anthropologist.

The general outline scheme of this Report is as follows:—

Anatomical dimensions:—

Introduction.
Terms defined.
Standard list.
Instruments to be employed.

Hair and eye colours :—

- Introduction.
- Pigmentation standards and meters.
- Hair colours.
- Eye colours.
- Tables of schemes of classification of hair colours and of eye colours.

Physiological measurements.

- Vision.
- Hearing.
- Tactile sensibility, &c.
- Muscular power.
- Spirometer tests.

Psychological measurements.
Environment.
Methods of recording photographic data.
Educational report.
Schedules.

ANATOMICAL DIMENSIONS.

INTRODUCTION.

To obtain successful and uniform results it is absolutely necessary that the observer should have a clear perception of the anatomical points between and around which the measurements are made. Certain anatomical terms and surface markings must therefore in the first instance be defined and explained. For the purpose of obtaining as high a degree of exactitude as possible in this direction, the Committee have introduced into the Report a series of illustrations of the human body which have been prepared by the Chairman (Professor D. J. Cunningham) with the assistance of Dr. David Waterston.

ANATOMICAL TERMS DEFINED.

Acromion.—The sharp border of bone at the top of the outer aspect of the shoulder. It can be detected most easily by passing the finger from behind forwards over the upper and outer aspect of the shoulder and pressing somewhat deeply. It is from the outermost point of the acromion that measurements are taken.

Anterior superior spine of the ilium.—A rounded projection or prominence which forms the anterior end of the iliac crest, or, in other words, of the curved upper border of the pelvic or haunch bone. As a rule the spine does not show with any degree of distinctness on the surface, and must be chiefly discovered by touch. To do this it is best to pass the finger from below upwards on the upper and outer aspect of the thigh until it is arrested by the bony prominence in question.

Canthi (outer and inner).—The angles of meeting of the two eyelids.

Condyles of the humerus.—The projections at the elbow-joint on either side of the lower end of the humerus or arm-bone. The *internal condyle* forms a prominence on the inner side of the limb appreciable to the eye; the *external condyle*, in a person of good muscular development, does not form a projection on the surface. It can be felt at the bottom of a slight depression on the posterior aspect of the limb.

Cranium.—The part of the skull which forms a protective bony covering for the brain.

Darwinian tubercle.—A small projection very frequently present on the free edge of the folded border (or helix) of the hinder part of the ear, near the summit of the auricle (see figs. 1 and 2). It is the morphological apex of the ear.

External and internal malleoli.—The prominent projections on either side of the ankle-joint. These are best felt from behind and below. The *external malleolus* is formed by the lower end of the fibula or outer bone of the leg, and reaches lower down than the internal malleolus. The *internal malleolus* is the broader of the two, and is formed by the lower end of the tibia, or inner bone of the leg.

Face.—The part of the skull which lies below the fore portion of the cranium. It is composed of the jaws and other bones which are arranged around the cavities of the orbits, nose, and mouth.

Frontal crests.—If the forehead is grasped between the finger and thumb immediately above and to the outer side of each of the orbits a ridge of bone will be felt curving upwards and backwards on each side of the cranium. This is the frontal crest.

Glabella.—Prominence in the mid-line of the forehead between the two eyebrows.

Great trochanter.—The outstanding projection at the upper end of the shaft of the thigh-bone (femur) external to the hip-joint.

Iliac crests.—The curved upper edges of the haunch or pelvic bones.

Iliac tubercle.—A projection on the outer edge of the iliac crest, about one and a half or two inches behind the anterior superior spine of the ilium.

Incisura intertragica.—The prominence in front of the ear-hole is the tragus; the prominence behind the ear-hole is the antitragus. The narrow interval between and below these prominences is the incisura intertragica (figs. 1 and 2).

Inion.—External occipital protuberance; a prominence on the under aspect of the back of the head and in the middle line, at the point where the curved outline of the back of the head meets the outline of the back of the neck.

Nasion.—The bottom or deepest part of the depression between the forehead (glabella) and the nose, or, in other words, the most depressed part at the root of the nose.

Occipital point.—The point in the middle line on the back of the head which is most distant from the glabella. It can only be determined by the callipers.

Ophryon.—A point, usually very obscurely marked, in the mid-line between the prominence of the glabella and the place where the frontal curve (*i.e.*, curve of the forehead) begins. It can also be determined by taking the mid-point of the transverse measurement across the narrowest part of the forehead from one frontal crest to the other.

Posterior superior spine of the ilium.—The projection at the posterior end of the iliac crest or curved upper border of the pelvic or haunch-bone. This spine is not easily felt, but its position is indicated by a very evident dimple in the skin above the buttock and about one inch or so from the mid-line of the back.

Pre-auricular point.—Point immediately in front of the tragus, or the little projection of the ear which lies in front of the ear-hole.

Pubic symphysis.—The median line of junction of the two haunch-bones in the middle line in front.

Styloid processes of radius and ulna.—The pointed projections which are directed downwards from the lower ends of the two bones of the fore-arm on either side of the wrist. The lower end of the ulna makes a marked rounded prominence on the back of the inner or little-finger side of the lower end of the forearm ; the *styloid process of the ulna* may be felt on the inner side of the wrist almost immediately in front of this prominence. The *styloid process of the radius* can be felt by placing the finger in the hollow on the outer side of the wrist, between the metacarpal bone of the thumb and the lower end of the radius, and pressing upwards.

Sub-nasal point.—The angle between the septum of the nose (*i.e.*, partition between the nostrils) and the upper lip.

Supra-sternal notch.—The depression on the upper margin of the sternum or breast-bone at the root of the neck and between the inner ends of the two collar-bones.

Zygomatic arch.—A bony arch on the side of the skull which can be felt stretching forwards from a point in front of the tragus of the ear to the most prominent part of the cheek.

STANDARD LIST OF DIMENSIONS OF THE HUMAN BODY SUITABLE FOR MEASUREMENT.

The subjoined dimensions of the human body which the Committee consider suitable for measurement cannot be regarded as constituting an exhaustive list. Still it includes most of the measurements which it has been customary to take, as well as a number of others which the Committee consider to be of importance. It is not suggested that all the dimensions in the list should be determined on each person measured, nor, indeed, in the course of any one investigation. Each observer can select from the list the particular dimensions he desires to record, and which he considers to be the most appropriate for the object he has in view.

A. Cranium.

The cranium is the part of the skull which forms the protective bony covering for the brain.

Diameters (Calliper Measurements).

1. *Maximum length.*—From the most prominent point of the glabella to the most distant point in the middle line on the back of the head, known as the occipital point. The observer stands on the left side

of the person being measured and the fixed point of the callipers is first applied to the glabella and held there by the fingers of the left hand, while the other point is moved over the mid-line of the back of the head (occiput). Care must be taken to observe that the fixed point has not moved off the glabella during the measurement, and that the points of the callipers have not been deflected from the median vertical plane. The pressure of the points of the callipers on the head should be as much as can be comfortably borne by the person under examination.

2. *Maximum breadth.*—Measured wherever it can be found above the plane of the ear-holes. The callipers should be held in a vertical transverse plane and moved about until the maximum diameter is ascertained, the observer being careful to keep the points of the callipers exactly opposite to one another. The pressure of the points on the head should be as much as can be comfortably borne by the person under examination.

3. *Minimum frontal diameter.*—From one frontal crest to the other across the narrowest part of the forehead.

Tape Measurements.

4 *Maximum circumference.*—Measured by passing the tape horizontally round the cranium at the level of the glabella in front and the occipital point behind.

5. *Longitudinal arc.*—Measured with the tape over the middle line of the vertex of the cranium from the nasion to the inion or external occipital protuberance.

6. *Transverse arc.*—Measured over the vertex of the head, in a vertical transverse plane, between the two *pre-auricular points* when the eyes are directed to the horizon.

Radii (Auricular Radiometer).

These radii may be considered to pass from the mid-point of the bi-auricular diameter to the various points indicated in the median longitudinal arc of the cranium. They are all to be measured by contact (*i.e.*, without perceptible pressure between the contact-point of the instrument and the skin of the head).

7. *Vertical.*—This gives the auricular height of the cranium. From the mid-points of the ear-holes to the highest point of the cranium measured in a vertical plane when the eyes are directed to the horizon.

8. *Frontal.*—(*a*) From the ear-holes to the most prominent point of the glabella ; (*b*) from the ear-holes to the ophryon.

9. *Maximum frontal.*—From the ear-holes to the most prominent point on the frontal curve.

10. *Occipital.*—From the ear-holes to the occipital point.

11. *Inial.*—From the ear-holes to the inion.

B. Face.

The face is the part of the skull which lies below the fore portion of the cranium. It is composed of the jaws and other bones which are arranged around the cavities of the orbits, nose, and mouth.

Calliper Measurements.

1. *Upper face length.*—From the nasion to the edge of the gum between the two upper central incisor teeth. A contact measurement.

2. *Total face length.*—From the nasion to the lower edge of the point of the chin. A contact measurement.

N.B.—*In connection with these measurements of face length it is important to state the condition of the incisor teeth.*

3. *Maximum interzygomatic breadth.*—The maximum diameter between corresponding points on the opposite zygomatic arches. The pressure used is to be as much as can be comfortably borne by the person under examination.

4. *Maximum intermalar breadth.*—The maximum diameter between the cheek-bones just below the angles or points of junction between the outer and lower parts of the rims of the orbital openings. A contact measurement.

5. *External orbital breadth.*—Maximum diameter between the outer margins of the orbital openings. A contact measurement.

6. *External ocular breadth.*—The diameter between the two external canthi of the eyelids. A contact measurement.

7. *Internal ocular breadth.*—The diameter between the two internal canthi of the eyelids. A contact measurement.

N.B.—*The two last measurements should be taken when the eyes are open.*

8. *Gonial breadth.*—The diameter between the extreme outer points of the angles of the lower jaw. This measurement is to be taken with the maximum comfortable pressure.

Tape Measurement.

9. *Orbito-nasal.*—From the same points as No. 5, the tape passing lightly over the nasion.

Radii (Auricular Radiometer).

All these are to be measured by contact only.

10. *Upper nasal.*—From the ear-holes to the nasion.

11. *Mid-nasal.*—From the ear-holes to the lower border of the nasal bones in the middle line.

12. *Lower nasal.*—From the ear-holes to the point of the nose.

13. *Alveolar.*—From the ear-holes to the margin of the gum between the two upper central incisor teeth.

14. *Mental.*—From the ear-holes to the point of the chin.

C. Nose.

Calliper Measurements.

(All these are to be measured by contact only.)

1. *Nasal height.*—From the nasion to the subnasal point.

2. *Nasal depth.* From the subnasal point to the most projecting point on the tip of the nose.

3. *Nasal length.*—From the nasion to the point of the nose.

4. *Nasal breadth.*—The greatest diameter, measured without pressure, between the wings of the nose.

5. *Nostril length.*—The greatest antero-posterior diameter of the nostril.

6. *Nostril breadth.*—The greatest diameter taken at right angles to the diameter of greatest length.

D. Ear.

Calliper Measurements.

To be taken by contact only.

1. *Length of ear basis.*—The length of the line drawn from the front upper insertion point of the auricle to the front lower insertion point (E, F, figs. 1 and 2).[1]

Fig. 1.

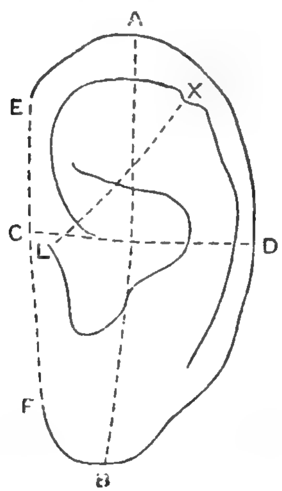
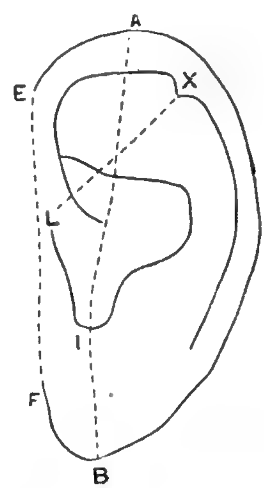


Fig. 2.



2. *Greatest length of the ear* (A, B, fig. 1).—From the highest to the lowest point of the auricle.

3. *Greatest breadth of the ear* (C, D, fig. 1).—The maximum diameter at right angles to the length-line from the ear basis to the hinder border of the auricle.

4. *Distance from the Darwinian tubercle to the upper border of the tragus* or the prominence in front of the ear-hole (X, L, figs. 1 and 2).

5. *Distance from the highest point of the ear to the bottom of the incisura intertragica* (A, I, fig. 2).

6. *Length of the lobule of the ear.*—From the bottom of the incisura intertragica to the lowest point of the auricle (I, B, fig. 2).

[1] Both from Schwalbe.

E. Trunk and Limbs.

Measurements from the Ground.

The subject is to be measured in the erect attitude, with his eyes directed to the horizon, his heels firmly planted, and the balls of the toes in contact with the ground. It is absolutely necessary that the subject should be symmetrically placed so that the mesial plane of the body is in every respect vertical.

The majority of the measurements can best be taken by means of the Anthropometric Wall-meter, seeing that this ensures a ready means of securing a proper position of the individual under examination.

All the measurements are to be made after the subject has removed his boots. It has been found that allowing for the height of the heel of the boot introduces serious error.

1. *Stature.*
2. *Height of the ear-hole.*
3. *Height of the acromion.*
4. *Height of upper edge of head of radius.*—When the arm is straightened at the elbow-joint a marked depression is seen on the posterior aspect of the outer part of the joint. If the finger be placed in this and moved slightly upwards and downwards the joint interval between the humerus and the radius will be felt. The lower bony margin of this interval is *the upper edge of the head of the radius*, and is the point from which this measurement is to be made.
5. *Height of the tip of the styloid process of the radius.*
6. *Height of the tip of the middle finger.*—When this measurement is taken the arm should be held by the side with the palm of the hand resting lightly on the outer side of the thigh.
7. *Height of the iliac crests.*—This is to be measured from the iliac tubercle.
8. *Height of the upper edge of the great trochanter.*
9. *Height of the knee-joint.*—This measurement should be made on both the inner and outer aspects of the joint, and in each case from the corresponding upper edge of the superior extremity of the tibia, or inner of the two bones forming the skeleton of the leg.
10. *Height of the tip of the internal malleolus of the tibia.*
11. *Height of the supra-sternal notch.*
12. *Height of the upper edge of the symphysis pubis.*
13. *Height sitting*, i.e., the length of the trunk from the vertex of the head to the lowest points of the ischial tuberosities (height from seat).
14. *Height kneeling.*

Direct Measurements

(*taken with callipers*).

15. *Breadth of shoulders* (*bi-acromial*).
16. *Maximum breadth of shoulders* (*bi-deltoid*).
17. *Distance between two anterior superior spines of iliac bones.*
18. *Distance between the two posterior superior spines of iliac bones.*
19. *Distance between iliac tubercles on iliac crests.*—This will give approximately the maximum diameter between iliac crests.
20. *Maximum diameter between the two great trochanters of the thigh bones.*

21. *External conjugate diameter of the pelvis.*—From a point behind midway between the posterior superior iliac spines to the upper and fore part of the pubic symphysis in front.

Measurements of Chest.

Circumference (taken with tape).

Direct the person being measured to hold the arms straight up over the head.

Pass the tape horizontally round the chest at the level of the junction of the fourth rib-cartilage with the sternum or breast-bone, then lower arms, and, holding tape tightly, note circumference at the end of—

22. *Deep inspiration.*

23. *Complete expiration.*—This latter is easily attained by asking the subject to count twenty aloud quickly without inspiring.

Before removing tape mark the level at which the measurements have been taken with a blue pencil around the chest.

If the finger be passed from the supra-sternal notch downwards over the front of the sternum or breast-bone it soon meets a projecting ridge, crossing the bone transversely. This gives the level of the *second costal cartilage*, and, taking it as the starting-point, the fourth costal cartilage, where it joins the sternum, can easily be determined.

Diameters (taken with Callipers).

24. *Antero-posterior diameter from mid-line in front to mid-line behind* (sternum to spine of dorsal vertebra) at the level of the blue line previously marked.

25. *Lateral.*—The maximum lateral diameter found with the callipers held horizontally and blades tangential to side of chest at the level of the blue line before referred to.

Both these latter measurements should be recorded (1) in deep inspiration ; (2) in complete expiration.[1]

F. Upper Limb.

1. *Length of the upper arm.*—From the outer margin of the acromion to the lowest point of the external condyle of the humerus. The latter point can easily be determined on the straightened arm by placing the finger in the depression on the back of the outer part of the elbow-joint and feeling for the joint interval between the humerus and radius. The measurement is made down to this point and gives approximately the length of the humerus.

[1] The reasons which have prompted the Committee to select the level of the junction of the fourth costal cartilage with the sternum for measuring the dimensions of the chest will be found stated at some length in the Report of the Anthropometric Committee, Section H, Leicester, 1907. The Committee are inclined to regard with favour the data obtained by the calliper measurements of the mesial antero-posterior and of the transverse diameters of the chest. For reasons which will be evident, useful data regarding the circumference of the chest, measured by the tape, cannot be obtained in the adult female. It is therefore recommended that the observer should restrict the chest measurements in the adult female to the determination of the diameters of the thorax obtained by means of the callipers.

2. *Length of the forearm.*—From the elbow-joint interval as defined in No. 1 to the tip of the styloid process of the radius. This gives the length of the radius.

3. *Length of the ulna.*—From the tip of the olecranon or point of the elbow to the extremity of the styloid process of the ulna.

4. *Length of the cubit.*—The elbow-joint being flexed, the measurement is made from the tip of the elbow on the back of the arm to the tip of the middle finger.

5. *Length of hand.*—Measured on the dorsum. The hand being dorsi-flexed, the position of the radio-carpal joint can be determined. It may be regarded as corresponding to the bottom of the angle which is formed between the hand and the forearm. Measurement is made from this to the tip of middle finger.

6. *Length of the thumb.*—From the base of the metacarpal bone to the tip of the thumb.

7. *Length of the four fingers.*—The three phalanges only are to be measured in each case. The measurement should be taken when the fingers are strongly flexed at the metacarpo-phalangeal or knuckle joints from points on dorsal aspect immediately in front of knuckles.

8. *Breadth of the hand.*—Taken across the knuckles.

9. *Maximum circumference of the upper arm.*—The upper limb should be straightened, but the muscles must *not* be contracted. The tape should then be passed round the upper arm where this shows the greatest girth.

10. *Maximum circumference of the forearm.*—The upper limb should be straightened, and the tape passed round the forearm where this shows the greatest girth. The muscles should *not* be contracted while the measurement is being taken.

G. Lower Limb.

1. *Length of the thigh.*—From upper edge of the great trochanter to the margin of superior extremity of tibia on outer side of knee-joint.

2. *Length of the leg.*—From the margin of the superior extremity of the tibia on the inner side of the knee-joint to the tip of the internal malleolus. This measurement gives the length of the tibia.

3. *Length of the foot.*—Two measurements : (*a*) from back of heel to extremity of second toe, counted from inner side ; (*b*) from back of heel to extremity of great toe. Both measurements taken with the foot resting on the ground.

A tracing of each foot should be taken.

4. *Breadth of the foot.*—Measured across the heads of the metatarsals, *i.e.*, from the prominent point on the inner side of the joint at the root of the great toe to the prominent point on the outer side of the foot at the base of the little toe, when the foot rests on the ground.

5. *Circumference of the thigh.*—This measurement is to be taken mid-way between pelvis and knee. The limb should be straightened, but the muscles of the thigh should *not* be contracted.

6. *Maximum circumference of the calf.*—The muscles should *not* be contracted while this measurement is being taken.

H. Special Measurements.

1. *Span of arms.*
2. *Weight.*

Where it is possible to do so the weight of the individual should be taken after he has divested himself of his clothes. The following symbols may be used to indicate how the weight has been ascertained :—

W^1. With clothes and boots.
W^2. With clothes but without the boots.
W^3. Without both clothes and boots.

3. *Teeth.*
4. *Finger-prints.*

INSTRUMENTS.

Weighing Machines.

The two leading types of personal weighing machine on the market are : (1) steelyard weighing machines, and (2) spring weighing machines.

I. *Steelyard Weighing Machines.*

In the most convenient form of steelyard weighing machine the steelyard is supported on the top of a pillar on a level with the eyes of the observer. The platform, on which the person to be weighed stands, is supported by knife-edges on levers housed in the base of the machine, and connected by a rod passing up the centre of the pillar to the short end of the steelyard.

A personal weighing machine of this type is made by W. & J. Avery, Ltd., Soho Foundry, Birmingham. It weighs up to 24 stones by single ounces. It is also graduated to weigh in metric measure. In weighing with this machine sufficient loose weights are first placed on a disc suspended from the outer end of the steelyard, the final adjustment being made by a small weight which slides on the steelyard. Another machine without loose weights is also made by the same makers.

A steelyard machine by Day & Millward, 39 Duke Street, Aldgate, London, weighs up to 12 stones without the employment of loose weights. The steelyard consists of two parallel graduated bars, on the lower one of which slides a heavy weight for weighing the larger units, while a light weight slides on the upper bar for weighing the smaller units and making the final adjustment. By suspending a loose weight on the end of the steelyard this machine is made capable of weighing up to 24 stones. The steelyard is graduated to weigh both in English and French measure.

II. *Spring Weighing Machines.*

Spring weighing machines are not so reliable as steelyard machines, because they are liable to be deranged by shocks or by leaving a heavy weight for a long time on the spring. They have, however, a great advantage over the steelyard machines in that persons can be weighed much more rapidly, and this is a quality of considerable importance when large numbers of persons have to be weighed in a short time. If these machines are frequently tested by placing a standard weight on the platform or scale and readjusted if necessary, there is no valid reason why they should not be used.

A platform spring weighing machine suitable for weighing school children is made by Geo. Salter & Co., 101 Leadenhall Street, London, E.C. It weighs up to 14 stones by $\frac{1}{4}$ lb.

A smaller machine for weighing infants is also made by the same firm. This machine weighs up to 25 lb. by ounces. The infant is placed on a table in a basket mounted on the top of the machine, which is conveniently placed.

For public schools or other institutions where speed and ease in weighing are considered of more importance than saving in first cost a seat weighing machine of the spring type made by Henry Pooley & Son, Ltd., Temple Street, Birmingham, may be recommended. This machine weighs up to 24 stones by pounds, and when protected from shocks is very accurate.

General Remarks.

Steelyard machines should be fitted with the best steel knife-edges. Cheap machines with cast-iron knife edges get out of order after being used a short time. It is recommended that machines graduated in the metric system should be used, and that all weights should be recorded in this measure whenever possible. English measure can, however, be easily converted into French by the use of a comparative table.

Height Meters.

For measuring statures and the heights of various points of the human body a considerable variety of apparatus is available. The simplest, perhaps, is a set square sliding on a rod 2 metres in length and graduated in millimetres. This rod may be fixed in a vertical position to a door or wall when it is required to measure stature only. When it is proposed to measure the heights of other points on the body the rod is preferably detached so that it can be held in one hand and placed opposite the point of the body to be measured. The rod may be fitted with a plummet to ensure its being held vertical. By attaching a set square at the beginning of the second meter, and making the lower half of the rod detachable, the apparatus may be used as a sliding callipers for measuring the transverse diameters of the body. An instrument of this kind is made by Messrs. Aston & Mander, 61 Old Compton Street, London.

Short graduated rods which do not reach the ground, but are fixed on doors or walls, are frequently used for measuring stature by applying a set square to their front surface. Such apparatus, though very simple and cheap, is liable to give inaccurate measurements: first, because it may not be fixed at the correct height; and secondly, because the surface to which the set square is applied may not be vertical.

A stature meter with a cast-iron pedestal fitted with levelling screws is made by Home & Rowland, Troughton Road, Old Charlton, Kent, and is very suitable as a permanent and fixed instrument for measuring the stature of school children.

A device for measuring stature as well as a large number of other dimensions of the body, horizontal as well as vertical, is the Wall-meter employed by Professor Cunningham in the Anthropometric Laboratory of the University of Edinburgh. This consists of a thin sheet of metal, wood, or other rigid substance divided into centimetre squares and fixed to the wall. The person to be measured stands in front of this, and the dimensions are read off by means of a set square. A great advantage of the Wall-meter is that it shows at a glance any lateral deformity or want of symmetry, and also whether the individual is standing in a proper position for measurement.

Callipers.

Wherever cheapness in first cost is a desideratum a sliding callipers of simple construction large enough to measure all the more important diameters, may be used. Such callipers are made by A. & J. Smith, Maxwell House, Aberdeen, and by other makers.

For rapid and accurate measurement of small diameters such as those of the cranium and face the large callipers are rather clumsy to handle, and it is advisable to use smaller callipers.

Flower's callipers may be employed for cranial diameters and for the smaller face dimensions by using the points at the back. Flower's callipers may be obtained from W. F. Stanley & Co., Ltd., 5 Great Turnstile, London, W.C.

Gray's self-adjusting constant-pressure callipers, made by Home & Rowland, are specially suited for measuring the length and breadth of the head, and the *compas glissière* used by Manouvrier is specially suited for small face measurements.

Radiometers.

For measuring auricular radii the instruments devised by Cunningham and by Gray may be used. In these instruments plugs fitted to the instruments are placed in the ear-holes and a sliding piece is pushed down (in the former instrument) or screwed down (in the latter instrument) till it just touches (without pressure) the peripheral point whose radius is to be measured.

Tapes.

The best appliance for measuring the girth of the chest or of other parts of the body is a tape graduated to millimetres, about 1 metre in length. A piece of string about 6 or 8 inches in length is connected to the zero end of the tape, or the tape itself may be extended 6 or 8 inches beyond the zero of the scale. By pulling this string and the other end of the encircling tape the necessary tension is put on, while the hands are kept clear of the reading point. If an inextensible linen tape can be obtained it is easier to work with than a steel tape, though the latter has the advantage that it can always be relied on as being absolutely inextensible.

Tapes may be obtained from Chesterman, Sheffield, or Aston & Mander.

For measuring span of arms a thimble may be attached to one end of the tape. This thimble is slipped on the fore-finger of one hand, and the measurement is read from the tape at the tip of the fore-finger of the other hand. The subject should stand in front of a wall, the arms being extended horizontally with the backs of the hands turned to the wall.

Finger-print Apparatus.

Finger-print apparatus consists of (1) a polished metal plate, about 4 inches by 12 inches, mounted on a wooden block about an inch thick; (2) a roller for distributing the ink; (3) finger-print ink in collapsible tube; (4) a good supply of benzoline; (5) a small reading glass. This apparatus may be obtained from Aston & Mander.

The polished metal plate is placed on a stand or table about 4 feet in height. About six drops of ink should be squeezed from the tube along the centre of the plate at intervals, and then thoroughly rolled until an evenly coated film of ink is spread over the whole surface of the plate.

To obtain an impression each of the subject's digits should be placed with one side in contact with the inked plate and rolled on the plate till the whole surface, up to the first joint, is inked. The impression is taken by repeating the rolling operation on a sheet of paper.

HAIR AND EYE COLOURS.

INTRODUCTION.

A considerable number of schemes of classification of hair colours and eye colours have been published, but it is only necessary to consider those that have been used to carry out extensive pigmentation surveys. Of these there are only two that appear to be important—namely, the scheme of Virchow and the scheme of Beddoe.

Virchow's scheme has been adopted more or less completely in carrying out a survey of about ten million children in Germany, Austria, Switzerland, Belgium, and Beddoe's has been generally adopted in observations made in the British Isles. These schemes are not in complete agreement, and it is desirable that a scheme should be devised that should be comparable with both. This is the chief object aimed at in the scheme drawn up by the Anthropometric Committee. Tables are given below showing the relation of the three schemes—namely, that of Virchow, of Beddoe, and of this Committee.

It is desirable also that a set of standard colours, representing the central colour of each category, should be determined. These standards should be permanent and should be easily obtainable by any person wishing to make exact observations on hair or eye colours. For less exact observations the names of the colours given in each category will suffice. In large surveys carried out by school teachers or other officials the cost of supplying standard colours to each observer may be prohibitive, but it must not be forgotten that there is a considerable amount of inconsistency between different observers when colours are determined by the names only. The Committee strongly recommend the use of standard colours whenever possible.

PIGMENTATION STANDARDS AND METERS.

Standard coloured glasses representing the central colours of each category of hair colours and eye colours have been prepared by and can be obtained from Mr. Lovibond, of the Colour Laboratory, Salisbury. These standard glasses are used for determining the colour of any given sample of hair or of eyes in the Pigmentation Meter, a modification of the Lovibond tintometer, adapted by J. Gray to observations on hair, eye, and skin colours. This instrument can also be obtained from Lovibond's Colour Laboratory at Salisbury. The Pigmentation Meter is described in 'Man' (vol. viii., No. 27, 1908).

A series of thirty-four standard coloured locks made of artificial silk, dyed to represent the usual hair colours, has been recently brought out by Professor E. Fischer, of Freiburg, Baden. These may be used in some cases with advantage. Each lock is marked with a number, which is used to designate the colour. The cost of the set of locks inclosed in a case is about one pound and may be obtained from Franz Rosset, surgical instrument maker, Freiburg.

HAIR COLOURS.

The schemes of classification of hair colours adopted by Virchow, by Beddoe, and by the Anthropometric Committee will be readily understood

Table I.

Schemes of Classification of Hair Colours.

VIRCHOW* [Pigmentation Survey of Germany, Austria, and Switzerland]		BEDDOE† [Observations in the British Isles]		BRITISH ASSOCIATION ANTHROPOMETRIC COMMITTEE, 1908		
Name of Category	Contents of Category	Name of Category	Contents of Category	Name of Category		Contents of Category
BLONDE	Light yellow Whitish yellow	FAIR	Yellow Flaxen Golden	FAIR	PURE BLONDE	Whitish yellow Yellow Flaxen Golden
	Ash blonde— Grey yellow Grey brownish Light brownish Red blonde		Lightest browns Pale auburns (with red inconspicuous)		ASH BLONDE	Ash blondes Lightest browns Pale auburns
RED	Fiery red	RED	All shades of *red* which approach more nearly to red than to brown, yellow, and flaxen	RED	LIGHT DARK	Same as Beddoe
BROWN	Brown Dark brown	BROWN	Numerous shades of brown, answering nearly to the French *chatain* and *chatainclair*	BROWN		Same as Beddoe
		DARK	French *brun*, darkest *chatain*, up to	DARK		Same as Beddoe
	Darkest brown	NIGER	Darkest brown	BLACK		Same as Beddoe's Niger
BLACK	Jet black		Jet black			

* *Archiv für Anthropologie*, vol. xvi. p. 281.
† Beddoe's *Races of Britain*, p. 3.

by an inspection of Table I. The main divisions of the scheme of the Anthropometric Committee are Fair, Red, Brown, Dark, and Black. These main divisions are the same as those of Beddoe, but fair hair is subdivided into *pure blonde* and *ash blonde*, mainly because these subdivisions have been used by Retzius in his extensive observations in Sweden. Red hair is subdivided into *light red* and *dark red*, because there is a considerable difference in the amount of orange pigment in the lightest and darkest red hair. Two or more of the main divisions may be amalgamated when a simpler scheme is desired.

In Virchow's scheme, as may be seen from the table, none of the divisions coincides exactly with those of Beddoe and of the Anthropometric Committee. The difference in the contents of the categories is, however, not great.

Mr. Lovibond has prepared seven standard glasses, representing the seven final subdivisions of the Committee's scheme. These glasses are adapted for use with the Pigmentation Meter.

EYE COLOURS.

The schemes of classification of eye colours are shown in Table II. The divisions of the scheme of the Anthropometric Committee are Pure Blue, Light, Neutral, and Dark. They agree with Beddoe's except that in Beddoe's scheme the pure blue and light divisions are amalgamated into one division. The pure blue coincides with a corresponding division in

Table II.

Schemes of Classification of Eye Colours.

<table>
<tr><th colspan="2">VIRCHOW*
[Pigmentation Survey of Germany, Austria, and Switzerland]</th><th colspan="2">BEDDOE †
[Observations in the British Isles, &c.]</th><th colspan="2">BRITISH ASSOCIATION ANTHROPOMETRIC COMMITTEE, 1908</th></tr>
<tr><th>Name of Category</th><th>Contents of Category</th><th>Name of Category</th><th>Contents of Category</th><th>Name of Category</th><th>Contents of Category</th></tr>
<tr><td rowspan="3">BLUE</td><td>PURE BLUE</td><td rowspan="2">LIGHT</td><td>Blue (all shades, including darkest blue)</td><td>PURE BLUE</td><td>Blue (all shades, including darkest blue)</td></tr>
<tr><td rowspan="2">GRAY</td><td>Bluish grey
Light grey
Lightest green</td><td>LIGHT</td><td>Bluish grey
Light grey
Lightest green</td></tr>
<tr><td>NEUTRAL</td><td>Very light hazel
Yellow
Green (most shades)
Hazel grey
Dark grey
Brownish grey and all uncertain colours</td><td>NEUTRAL</td><td>Same as Beddoe's</td></tr>
<tr><td>BROWN</td><td>Brown
Black</td><td>DARK</td><td>Brown
Dark brown
Black</td><td>DARK</td><td>Same as Beddoe's</td></tr>
</table>

* *Archiv für Anthropologie*, vol. xvi. p. 281.
† Beddoe's *Races of Britain*, p. 3.

Virchow's scheme. The division *grey* in Virchow's scheme includes both the light and neutral of the Committee's scheme. In Virchow's scheme pure blue and grey are subdivisions of a larger division blue.

Standard glasses for use in the Pigmentation Meter, and representing the central colours of the four divisions in the Committee's scheme, may be obtained from Mr. Lovibond.

PHYSIOLOGICAL MEASUREMENTS.

In making survey tests the observer must bear in mind the fact that the success of the process presupposes the goodwill of the subject, and he must consider in each case the possibility of 'malingering' on the part of the subject.

VISION.

I.—The test of *visual acuity* seems both the most important and the most easily applied of all visual tests. It is desirable that the method used should be applicable to subjects who have not learned to read. Cohn's modification of Snellen's E test is therefore recommended as one which meets this requirement, and which has been employed with satisfactory results on uneducated children and adults. Of the several forms in which this test has been used the one in which the test E is presented alone through a window in a screen is recommended.[1]

The test-card should be held vertically in strong diffused daylight at the zero point of a scale of metres marked on the ground. The background on which the test-card appears should be a dull surface, and there should be no bright light (such as that from the sky) falling directly upon the eyes of the subject.

The subject should be brought up to a point on the metre scale at which the test E is clearly visible to him and be instructed to turn his E (pasted on board) into same position as the test E exposed. This should be repeated five times by subject in his first position, and five times at each point of the scale successively one metre further from the test E. If at any position the subject makes more than one error (which he fails to correct on being informed of it) the previous position (one metre less distant) may be taken as the measure of his visual acuity. If he makes one error only in the series of five tests five further tests should be made at the same position. If he again makes one error (*i.e.*, two errors in ten tests) this position may be taken as the measure of his visual acuity. The visual acuity will then be expressed simply in terms of the number of metres between the test E and the position of the subject when he just satisfies the test.

The subject should be tested without glasses or any other artificial aid to vision.

COLOUR-VISION.

II.—Holmgren's wools are so convenient a form of test that they are to be preferred to the more refined methods that have been devised. This method can be relied upon to reveal the commonest forms of

[1] The cards may be obtained from Glaisher, 57 Wigmore Street, London, W.

colour-blindness, though it may fail to detect degrees of weakness of colour-vision.

The three test wools of the Holmgren set should be given each separately to the subject, and he should be asked to choose the ten other skeins most nearly resembling the test-skein, and to lay them out on the table in order of resemblance. Any naming of the colours should be avoided until the subject has completed his selection, when he may, with advantage, be questioned as to the names he would apply to the test-wools. If the subject chooses wools of distinctly unlike colour-tone, but of similar low saturation, it should be explained to him that differences and resemblances of shade and of saturation are to be neglected and those of colour-tone only regarded. Any grouping of distinctly green tones with red, or of red with green, if not readily rectified, must be taken as evidence of red-green blindness. Any hesitation in distinguishing between red and green tones should lead to a more searching examination. From this point of view it is important to observe what wools the subject picks up and rejects, as well as those which he finally selects.

If time permits, each eye should be separately tested.

The modified tintometer (designed by Mr. Lovibond for colour-vision testing), in which the place of the coloured wools is taken by slips of coloured glass presented against a white background, may be used in place of the wools, but a larger series of glasses of lower saturation than that at present supplied with the instrument would be required. Special attention should be paid to the matches made with red and green glasses of low saturation. A red glass of low saturation should be placed in the topmost space of the one vertical row and a green glass of low saturation in the topmost space of the other vertical row as 'test-glasses'; the remaining spaces may then be filled with glasses of various tones and degrees of saturation, and the subject directed to resort them, placing them beneath the 'test-glasses' in the order of their resemblance to the test-surfaces.

This test may with advantage be made, first, with the apparatus at a distance of 5 metres from the eye of the subject and then repeated at a distance of 30 to 50 centimetres.

TESTS OF HEARING.

Auditory Acuity.

To be measured in terms of the distance (number of metres) at which the stroke of Pollitzer's 'Hör-messer' can just be heard.

The subject must be seated in a large, quiet room, or, better, in the midst of an open space at some distance from all solid objects. The subject's eyes being closed and bandaged and the left ear stopped with the finger, the instrument must be sounded at irregular intervals of two or more seconds in a series of positions in the straight line passing from ear to ear, first at 1 metre from the right ear and then at positions successively 1 metre more distant from the ear. The subject is instructed to say 'Now' each time he hears the stroke. When the subject fails to respond to a stroke it must be repeated five or more times in the same position. The series must be continued until a position is reached at which the subject fails to respond more frequently than he succeeds.

The immediately preceding position may be taken as the measure of auditory acuity of the right ear. The procedure is then to be repeated on the left side, the right ear being stopped, for the determination of the threshold of auditory acuity of the left ear.

TACTILE DISCRIMINATION.

To determine the threshold of local discrimination of two simultaneous touches on the skin.—The area most suitable for the application of this test is the middle third of the flexor surface of the left forearm. An æsthesiometer with two ivory points, of which one slides along a millimetre scale, should be used (Dr. Spearman's pattern is recommended).

The subject must be comfortably seated, his left forearm bared and supinated and resting upon a pad on the table at a convenient height, while he supports himself by placing his right forearm on the table and across his chest.

The two points are applied suddenly and simultaneously in a line parallel to the long axis of the forearm, with pressure sufficient distinctly to pit the skin, and continued for about one second. The two points are separated by 80 mm. A series of five applications of the two points at this distance is irregularly interspersed with five applications of a single point. Each contact should be preceded by a warning 'Now.' The subject is instructed to answer 'Two' or 'One,' according as he judges that he is touched with two points or with one only. He is immediately informed as to the correctness of each answer. If the individual under observation makes no erroneous answers the distance between the two points is reduced to 70 mm., and the series of five double and five single touches is repeated. The same procedure is repeated with two points at 60 mm., 50 mm., 40 mm., 30 mm., 25 mm., 20 mm., 15 mm., 10 mm., 5 mm. When the person being tested gives one or more erroneous replies to double contact in any series of five the series is prolonged to ten double and ten single contacts. A proportion of two wrong answers to eight right in response to the series of ten double contacts is taken as indicating that the distance between the two points is the measure of the threshold of discrimination. If the answers to the double contacts of any one series are to have significance the answers to the single contacts of the series must be oftener right than wrong. The answers of the person under observation should be recorded thus :—

30 mm.	Single touches	∠	∠	∠	∠	×	×	∠	×	∠	∠
	Double touches	∠	∠	×	∠	∠	∠	∠	×	∠	∠

The answers recorded in this example would indicate that 30 mm. is the measure of the sensible discrimination of the subject.

If the individual being tested makes no errors at one step (say 40 mm.), and breaks down completely at the next step (say 30 mm.), the length midway between the lengths separating the two points in the two cases may be taken as the measure of sensible discrimination.

MUSCULAR POWER.

To measure power of grip a dynamometer to be obtained from Collin, 8 Rue de l'Ecole de Médecine, Paris, may be used. The subject should squeeze the instrument with the greatest possible effort three times in each hand, using the two hands alternately, and the maximum squeeze with each hand should be recorded.

To measure power of pull as archer a dynamometer with two handles is used. The subject should grasp the handles and straightening the left arm should pull the right hand with all his force. Repeat three times and record maximum pull.

SPIROMETER TESTS.

Spirometers may be obtained from various makers, as, for example, Zimmermann, of Leipzig.

In making spirometer tests the same rules are to be observed as stated above for muscular power.

PSYCHOLOGICAL MEASUREMENTS.

The list of mental characters drawn up by Mr. McDougall and embodied in the Report submitted at the York meeting of the Association has been discussed at two meetings of the British Psychological Society, and has been amended and extended by the Sub-Committee in the light of these discussions. The amended list is submitted with this Report.

The Sub-Committee recommend that the list should be printed, and that, before any use of it on a large scale is attempted, it should be issued to a limited number of specially qualified school-teachers, who should be invited to fill in the schedules of characters for groups of pupils with whom they are well acquainted. In this way, it may be hoped, some data may be obtained for the formation of an opinion as to the applicability and reliability of this method of procedure. From this point of view it appears especially important to secure independent returns from two or more teachers in regard to identical groups of pupils, as the degree of correspondence between two or more such independently made Reports referring to the same group of pupils would indicate the degree of objectivity of the Reports.

The Sub-Committee are of opinion that, though data of some value may possibly be obtained by the issue of the list of mental characters to school-teachers and others, the survey of mental characters cannot be satisfactorily carried out save by the aid of observers specially trained in the methods of mental measurement, who would make a series of measurements of the capacities of each individual according to a scheme which has yet to be drawn up; they recognise that the estimation of mental characters is very much more difficult than that of physical characters, and that it is necessary to proceed in a tentative and experimental spirit. They would especially insist on the difficulty of fixing any common standard and of obtaining returns which shall have an absolute value and shall be comparable with one another, except in so far as returns can be based on exact measurements made by the methods of experimental psychology.

(Amended) Instructions to the Recorders.

Mental characters are named, numbered, and briefly defined in this Schedule.

The accompanying card bears a corresponding number of numbered spaces.

The Recorder should put the name of one subject (child, &c.) at the head of each card, and write 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 :—

A. High degree of development, intensity, or strength of the character in question.

B. A degree of development distinctly above the average.

C. An average degree of development.

D. Degree of development distinctly below the average.

E. A marked deficiency of the character in question.

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 persons of the same age, race, and 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.

The Recorder should fill in on each subject's card only those characters in regard to which he feels able to express a confident opinion, and should leave all other spaces blank.

It is suggested that the following procedure should be adopted whenever possible, especially by those reporting on school-children : A table of thirty-four columns, numbered according to the list of characters, should be made on a large sheet of paper, and under each number the individuals of the group observed should be entered in the order of development of the corresponding character (those considered equal being bracketed together). This should be regarded as a first rough approximation only. From time to time the observer should go over his table, amending the order of names in each column in the light of his later observations. If this process were repeated once a month or oftener throughout a year's intercourse with the group of individuals reported upon, it is probable that the final arrangement of each column would represent a great refinement upon the order first given.

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.*, laziness does not appear, because a high degree of laziness is the same character as a low degree of industriousness, and may be expressed by putting the letter *E* after the corresponding number on the card.

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. Power of 'observation' or sense-perception,

    (*a*) Accuracy.
    (*b*) Fulness (*i.e.*, degree to which attention is habitually given to objects of the outer world rather than to reflection and imagination).

2. 'Quickness' of apprehension in general.

3. Scope of apprehension (*i.e.*, capacity for apprehending complex relations and multiplicity of detail).

4. Intensity of application to mental tasks (*i.e.*, power of 'concentration' of attention; this may be taken to be inversely as the readiness with which attention is distracted from the task in hand by irrelevant objects and impressions).

    (*a*) Spontaneous or non-voluntary.
    (*b*) In virtue of effort of will.

5. Capacity for sustained application (*i.e.*, for sustaining and repeating concentration of attention upon given task='perseverance').

    (*a*) Spontaneous.
    (*b*) In virtue of effort of will.

6. Natural or spontaneous 'interests' (*i.e.*, interests in objects or topics for their own sake, not indirectly acquired by special training or through such influences as emulation or systematic reward and punishment).

    (*a*) Intensity.
    (*b*) Variety or width of field of interests.
    (*c*) Persistency of interests in particular topics and objects.

7. Native 'retentiveness' of memory as expressed, *e.g.*, by accurate reproduction of matter committed to memory by rote learning or by capacity for describing objects or events of no special interest previously observed.

    (*a*) Immediate, *i.e.*, as revealed after brief interval of few minutes only.
    (*b*) Continued, *i.e.*, as revealed after interval of twenty-four hours or more.

8. Systematic memory (*i.e.*, retention of facts in virtue of the apprehension of their connection with topics of special interest to the individual, or because systematically related with one another).

9. Selective memory—exceptional retentiveness for certain classes of impressions, or for facts about certain subjects.

10. Vividness and detailed accuracy of representative imagination (*i.e.*, power of recalling past sense-impressions in corresponding imagery).

11. Freedom and range of play of 'fancy' (*i.e.*, in popular speech—imaginativeness).

12. Purposive constructive imagination (*i.e.*, 'inventiveness,' or the power of bringing things together in imagination in relations in which they have not previously been experienced, under the guidance of the idea of some end to be achieved).

13. Power of 'logical inference' or reasoning.
14. Confidence in his own observations, judgments, and inferences.
15. Freedom of expression of feelings and emotions.
16. Liability to anger.

    (*a*) Readiness with which the emotion is excited;
    (*b*) Intensity of the emotion;
    (*c*) Duration of the emotion.

17. Fear.

    (*a*)
    (*b*) } Same as 16.
    (*c*)

18. Curiosity.

    (*a*)
    (*b*) } Same as 16.
    (*c*)

19. Joyousness.

20. Sympathy (the tendency to be moved by an emotion when the expression of it in another person is witnessed—*i.e.*, primitive sympathy).

21. Courage or resolution (*i.e.*, not mere absence of fear, but degree to which purpose is pursued in spite of pain, fear, opposition, and of difficulties foreseen).

22. Altruism (the tendency to put the welfare of others, individuals or the public, before one's own as a motive of action).

23. Egoism (the frequency with which the idea of one's self and its relations is the ruling motive in action and the mainspring of the emotions).

24. Conscientiousness (tendency for action 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).

25. Industriousness.

26. Sensitiveness to opinions of other individuals (*e.g.*, of teachers or schoolfellows) or to public opinion (this is not to be confounded with conscientiousness or with suggestibility).

27. Sociability (the finding of pleasure and satisfaction in the society of fellows).

28. Initiative (expressed, *e.g.*, in tendency to assume leadership in games, in class, &c.).

29. Masterfulness—the tendency to impose one's own will and opinions upon others.

30. Suggestibility—readiness with which opinions and beliefs are impressed by the expressions of other persons.

31. Competitive or emulative spirit.
32. Sense of ludicrous.
33. Æsthetic feeling.
34. Energy (*i.e.*, capacity for doing work without exhaustion):

    (*a*) Bodily work;
    (*b*) Mental work.

ENVIRONMENT.

INTRODUCTION.

The environment may be regarded as affecting the evolution of mankind in two different ways :—

(1) It may affect the growth and activity of living bodies, and thus produce a more or less efficient population from any given stock.

(2) It may change the quality of the stock by selection.

The first controlling action of the environment may be called *trophic action* ; and the second, *genetic action.*

The trophic factors of the environment include nutrition, physical exercise and training, education, stimuli (physical and mental), inhibition (physical and mental).

The genetic factors of the environment include all those influences which control the relative rate of increase of the more or less endogamous grades or classes of varying efficiency into which every population may be divided. The rate of increase of any given class evidently depends on the difference between its birth-rate and its death-rate. All factors of the environment which influence the birth-rate or death-rate of a class of the population have a genetic action, *i.e.*, in the course of time they may change the average quality of the stock.

Any of the actual factors of the environment are probably capable of acting more or less both trophically and genetically. The kind of action of each factor must be determined by observation of the changes which they produce when they have been acting for a sufficiently long time on sufficiently large groups of men. It would be impossible, therefore, to rigidly classify the factors of the environment according to the kind of their action on mankind, though we may fairly assume that the action of some factors is mainly trophic, and of others mainly genetic.

Factors of the environment may also be classified according as they act mainly on the bodies or minds of men, as *physical*, or *psychological.*

The factors selected for observation should preferably be of such a kind that a numerical estimate can be made of their degree or intensity. In many cases where the degree cannot be given in the case of individuals the presence or absence of the factor may be noted. When this has been done, in the case of a sufficient number of individuals, the intensity of the action of the factor on the group may be estimated as a percentage.

In making observations on the environment of a group of individuals we may know that many factors are common to all individuals in the group. Such factors should not be noted on the individual schedule, but should be noted on sheets or cards applying to the whole group.

It is not sufficient to note the factors of the environment in which the individual or group of individuals is living at the time of the observations. As far as possible a history of the past environment should be obtained.

LIST OF FACTORS OF THE ENVIRONMENT.

The following is a list of the more important factors of the environment, with suggestions as to methods of observation :—

Food.—The kind of food, whether, for example, vegetable or animal, the number of meals, per day and the weight of each kind of food consumed at each meal. In many establishments there is a fixed menu which is the same for each individual. In that case the menu need only be entered once in the general notes on the group.

It might be of interest to note how far the amount of food provided corresponds with the amount actually consumed.

Drink.—The same kind of remarks apply to drink as to food.

Tobacco, &c.—The quantity or kind of tobacco, or any kind of drug, habitually consumed by the individual should be noted.

Clothing.—The quality and quantity of clothing.

Climatology.—The statistics of temperature can be got from meteorological observations where such exist. Notes may be taken as to whether the country is mountainous or low-lying and flat, whether the habitat is urban or rural.

Sanitation.—The general facts as to systems of drainage (wet or dry systems), ventilation, &c., should be noted. Number of rooms in dwelling is a very valuable indication of sanitary life of the individual.

Work.—Kind and hours of work.

Physical training.—System of gymnastics and hours of day regularly devoted to training should be noted. Also military training, kind and amount of, or any other training special to individual or class ; bathing ; hours in open air.

Recreation.—Kind of sports or games and time regularly devoted to them may be noted.

Sleep.—Hours of actual sleep per day. Note whether sleep is disturbed.

Education.—In recording the history of the education of the subject an account should be given of the home, school, and university environment. The number of children and sex of the children in family, the occupation of parents, whether one or both parents are dead, education of parents, religion of parents.

The kind of school or schools attended. Co-education or not.

The university attended and the nature of the studies, whether classical, scientific, or technical.

The time and kind of business training.

Wealth.—This may be indicated by noting wages or income where possible. The number of domestic servants per unit of the population is a valuable indication of wealth.

Leisure.—Hours devoted to work and recreation if already ascertained above will give a fair indication of leisure.

Marriage and sex conditions.—It should be noted whether the subject is married or single, or has been married and how long. The number of children and their ages (if not previously noted). Existence of prostitution and venereal diseases in the community has an important bearing on this branch of the subject.

Psychological factors.—The conduct and evolution of the individual will be very much influenced by the public opinion of the community in which he lives. The political opinions, love of liberty, patriotism, individualism, socialism, morality, or any other widely spread beliefs of the community or associates of the individual should be noted.

GENERAL DIRECTIONS.

It is not intended that the whole of the factors indicated in the above list should be noted in the course of all investigations. A selection should be made of the factors in which the observer is most interested, and this should be adhered to throughout the investigation in question. In many cases good practical methods of estimating the various factors may suggest themselves to the observer though they are not given in the above list. In general it may be observed that it is safer to collect statistics of a few factors with certainty than of a larger number where the authenticity is more doubtful.

METHODS OF RECORDING PHOTOGRAPHIC DATA.

Racial characteristics are conveniently recorded by means of photographs. In every case the name, sex, age, and nationality (including tribe, clan, or group), and also the date and place at which the photograph was taken, should be recorded, and an identifying mark should be placed on every negative. The portraits which are of anthropological value are as follows :—

A. General Characteristics.

(*a*) A few portraits of such persons of each sex as may, in the opinion of the observer, best convey the special characteristics of the race as regards features and pose of body. These should be taken in the aspect which best displays those characteristics, and should be accompanied by a note directing attention to the special features shown in the photograph. It is desirable that some of these portraits should *not* be taken either strictly full-face or in strict profile. Very interesting series are afforded by whole families. Snapshot photography often gives more characteristic records of expression and pose than can be obtained by formal sittings before a stand-camera.

(*b*) Special photographs should be taken to record all characteristic deformations of the head, face, teeth, and other parts of the body ; and all forms of tattooing and scarification should be recorded by photographs taken in the aspect which best displays the peculiarity. Scarifications almost always demand special sidelong illumination ; tattooing also sometimes needs orthochromatic plates. It is occasionally necessary to enhance tattoo marks with black paint on the person ; but this should be avoided if possible.

B. Portraits of Head and Face only.

(*a*) The portraits should show in each case the left side of the face in exact profile. At least twelve male adults and twelve female adults should be photographed. The hair should be so arranged as fully to show the ear, and the males should be beardless if possible. If time only admits of a smaller number, or of only one sex, males should be preferred. To obtain the best average definition, the image should be focussed on a plane midway between that of the ear and the mesial plane of the head. For detailed directions as to pose, illumination, &c., see below.

(*b*) The same persons who were taken in side-face should be photographed also in strictly full-face. The focal plane should be that of the front of the cheek.

(*c*) The same persons should be photographed also, if possible, so as to show the top of the head. This, however, is only of value if the subject is bald or shaven, or has very close-cropped hair.

It will add much to the value of the portraits if the same persons have also been measured.

C. Full-length Portraits.

At least twelve adults of each sex should also be photographed at full length, standing, with heels together and arms by the sides. They should be as nearly nude as circumstances permit, and each should be photographed in three positions :—

(*a*) Full-face, with the right arm hanging loosely by the side and the left held across the body between the breasts and the navel, with the fingers extended.

(*b*) Profile with arms hanging loosely by the side.

(*c*) Back view, with arms in the same position as in (*b*).

Of these the full-face view is the most important, and the back view the least important.

For general directions as to pose, &c., see below.

General Directions.

Camera and Lens.—In all cases record should be kept of the focal distance of the lens and of the distance of the sitter from the camera.

A lens of short focus should be avoided. The ordinary field camera is usually fitted with a lens of about 8 inches focal length, but for cabinet portraits nothing under 15 inches is satisfactory, and professional photographers often use lenses of considerably longer focus. Valuable results may even be obtained with a telephotographic lens such as is employed in geographical work.

Rapidity of lens and plates is an advantage : uncivilised folk are impatient subjects. But note that very rapid plates are often too delicate for field-work.

The focussing screen must be kept vertical, and the swing-back should on no account be used in focussing. Otherwise distortion of the image is inevitable.

Size and Scale.—The portraits should be on such a scale that the distance between the top of the head and the bottom of the chin shall in no case be less than $1\frac{1}{4}$ inch (30 mm.). Smaller portraits are of comparatively little value.

For composite work greater uniformity of scale is required. The best results are obtained when the distances between eyes and lips are taken as the constant dimensions.

In every series it is more important that the portraits should be of uniform scale among themselves than that they should be precisely of any standard scale, but the following hints will aid in securing the latter result also :—

Full-length Portraits.

A full-grown man can be photographed easily at full length on a 'half-plate' ($8\frac{1}{2}'' \times 6\frac{1}{2}''$) on the scale of $\frac{1}{10}$, and on a 'quarter-plate' ($4\frac{1}{4}'' \times 3\frac{1}{4}''$) on the scale of $\frac{1}{20}$. But 'half-plate' and 'quarter-plate' are both just too small to admit head-and-shoulders portraits on the scale of $\frac{1}{3}$ and $\frac{1}{4}$ respectively.

Note, however, that the École d'Anthropologie de Paris has adopted the scale of $\frac{16}{200}$ ($=\frac{8}{100}=\frac{1}{12\frac{1}{2}}$) for full-length work, the object being to secure full-length portraits on the French '13×18 cm.' plate (approximately the English $5'' \times 7''$ size). See *Rev. Ec. Anthr.* viii. (1898), p. 109.

Head-and-Shoulders Portraits.

The 'half-plate' and 'quarter-plate' are just too small to admit with security a head-and-shoulders portrait on the scale of $\frac{1}{2}$ and $\frac{1}{4}$ respectively.

The French scale for these portraits, and for other parts of the body in detail, is $\frac{16}{40}$ ($=\frac{4}{10}=\frac{2}{5}$), which permits a head-and-shoulders portrait to be taken easily on a '13×18 cm.' plate, and with ample margin on a 'half-plate.' Similarly on the scale of $\frac{1}{5}$ a 'head-and-shoulders' portrait can be taken easily on a 'quarter-plate.'

Scale and Label.—A board, on which is marked very legibly a scale of feet and inches and also a 'metric' scale, should be suspended over the head of the subject in the plane of his profile, and so as just to fall within the photographic picture. This is the only certain method of preserving a record of the scale, and also makes it easy to secure whatever scale of reduction may be adopted, by comparison of the image of this board with a line or rectangle of proportional size drawn on the focussing screen of the camera.

The name of the district and of the sitter (or at all events a distinctive letter or number) may be written with chalk or charcoal on this same board, thus securing the identification of each subject.

Background.—The background should be at a considerable distance from the subject. It should be of a medium tint (say a deep shadow, or a sheet of light brown or french-grey paper pinned against the wall beyond), very dark and very light tints being both unsuitable. Some, however, use dead black; others, red baize. A soft material which does not readily crease obviates trouble from accidental shadows. In any case due allowance must be made for the complexion or skin colour of the persons to be photographed; and preliminary experiment is advisable. A note should be made of the colour of the background, and also of the complexion or skin colour of the subject.

The essential condition is that the outlines of the figure shall be clearly defined against the background.

Illumination.—The incidence of the light should be the same in all cases, otherwise the photographs are difficult to compare, and cannot be used to make composite portraits.

The source of light should be single, definite, and placed behind the camera and above it, so that the shadows may be equally distributed on either side of the face. This is especially important for composite work.

The light, however, must not be so strong or concentrated as to distress the subject or cause him to close or strain his eyes. But note that subdued light involves longer exposure. A dark background behind the camera relieves eye-strain, without cutting off top-light. When the top-light is strong, a white sheet on the ground lightens the shadows, and helps to prevent the subject from looking down.

Mounting.—The photographs should be *mounted on cards*, each card bearing the name of the district, and a letter or number to distinguish the individual portraits; the cards of each series may be secured together by a thread passing loosely through a hole in their upper left-hand corners.

For convenience of comparison and interchange, attention is called to the standard sizes of mounts adopted by the British Association's Committee on Anthropological Photographs. The ordinary 'cabinet-mount' is used for all sizes up to and including 'half-plate.'

The risk of fading is minimised by avoiding gum or paste; each print being secured by its corners to slits cut in the mount, as in a post-card album. But the only complete security is the use of a really 'permanent' process such as Platinotype.

Detailed Directions as to Pose.

For purposes of comparison, uniformity of pose is essential in photographs in classes *B* and *C* (see above).

For *side-face* (B^a) and for *full face* (B^b) the head should be posed so that a line drawn from the inferior orbital margin to the tragus of the auricle is horizontal. This is a test which can be directly applied in either pose with the help of sights and a level on the side of the camera; for the axis of the camera should lie in the same horizontal plane with the line from the inferior margin of the orbit to the tragus.

Without such provision for uniformity, differences of face projection and prognathism are liable to be obscured or misrepresented.

The subject should look at some object on a level with his eye and at a moderate distance from it.

For *top view of the head* (B^c) the following methods are practicable:—

1. Set the camera on a high stand, pointing vertically downwards, and make the subject sit on the ground below it, with his head posed as for side view.

2. Set the camera to point horizontally, and make the subject lie on his back on a table of suitable height, with his head towards the camera. The line from the inferior margin of the orbit to the tragus should now be vertical.

3. Set the camera to point horizontally; set a chair with its back to the camera; make the subject sit straddlewise on the chair, facing the camera; let him fold his arms on the back of the chair, and bend forward, resting his head on his arms, and looking downwards, till the head is in the right pose; when a plumb-rule will test the line from the inferior margin of the orbit to the tragus.

Suggestions for Rapidity and Uniformity.

By attending to the following hints, successive sitters may be made to occupy so nearly the same position that the camera need hardly be refocussed:—

1. Much time will be saved if all the side-faces are taken first, and then all the full-faces; the latter should occupy a different chair, in which case the position of the camera would require to be changed after com-

pleting the first series of photographs; unless, indeed, there happen to be two operators, each with his own camera, ready to take the same persons in turn.

2. If the camera has a stand with vertical rack-and-pinion adjustment, the subject's place should be fixed, and the camera should be raised and lowered to suit each subject. A square of the standard size of the picture should be ruled on the focussing screen of the camera.

3. For field work, and wherever the camera has no such adjustable stand, the camera should be set at a fixed height and all the subjects should occupy in turn the same chair, with movable blocks of known thicknesses on the seat to raise the heads of successive sitters to a uniform height. It is, however, tedious and clumsy to adjust each sitter's height by trial in front of the camera. The simpler plan is to make the sitter first take his place on a separate seat with his back to a wall, on which are previously marked, at heights corresponding to those of the various heights of head, the numbers of the blocks that should be used in each case. The appropriate number for the sitter is found and noted, and then the proper blocks are placed on the chair by the observer or an assistant, with the assurance that what is wanted has been correctly done.

4. The position of the sitter is easily controlled by the operator if he looks at the sitter's head over the middle line of the camera, against a mark on the background.

The subject can also be caused to adjust himself approximately by means of sights arranged on the side of the camera, as follows :—

A is a small mirror with a cross + painted on it. It is set at an angle of 45° to the sitter's line of sight.

DIAGRAM A.

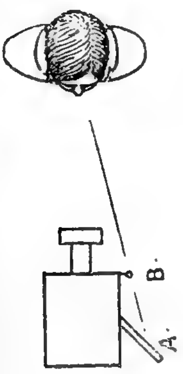
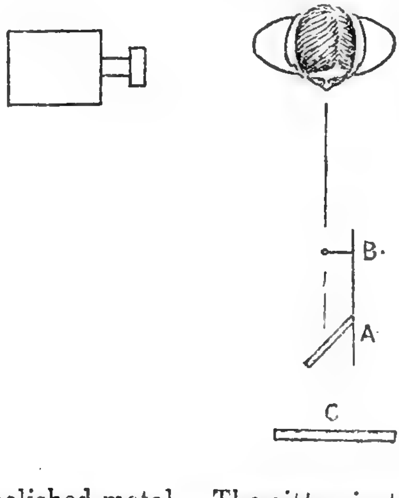


DIAGRAM B.



B is a pin with head of glass or polished metal. The sitter is told to keep the head of the pin sighted in the intersection of the cross.

The same device may be employed in photographing side-face to keep the sitter in the right focal plane. In this case the sights are set up in the focal plane, facing the sitter. Or a small plain mirror (*C*) may be hung up, so that the sitter can only see his face in it when he is in the right pose and focal plane.

EDUCATIONAL REPORT.

In dealing with anthropometrics in schools the chief factors which the Sub-Committee has had to take into consideration are time, expense and the object of the investigations. If time and expense did not enter into the question, it is hardly necessary to remark that, from the scientific point of view at least, the measurement of school-children would require no special scheme of observations as apart from a general survey of the population. In present circumstances, however, when a crowded curriculum reduces the time available for anything outside the absolutely essential to a minimum, and the cost of the education of the large majority of the children is borne by public funds, it is necessary to confine the investigation, so far as possible, to a practical issue more or less immediate.

From an educational point of view the value of an anthropometric survey must lie chiefly in the fact that it affords an accurate indication of the development of the individual, and at the same time provides those responsible for education with some means of judging how far the individual, or individuals, of a particular area are modified, physically and mentally, by the education provided.

The Sub-Committee is therefore of the opinion that the aim of anthropometric observations in schools should be :—

1. To determine norms or averages, standard deviations and correlations at different ages, having due regard to sexual, racial, and environmental differences.

2. To correlate physical and mental growth with a view to testing the efficiency of different systems of education and indicating the amount of work that may advantageously be attempted at different ages, thereby minimising the dangers of over-pressure.

3. To mark out the physically or mentally unfit for special educational treatment. Where the deviation is abnormal in a number of individuals, a whole school, or a whole area, it would point to the necessity for special investigations of social conditions and environment.

4. To correlate physical, mental, and environmental characters with a view to providing a scientific basis for the better adaptation of education to local needs and character.

As regards the anatomical measurements the Sub-Committee recommends the adoption of the schedules suggested for use in schools in this Report.

The adoption of a particular schedule must depend largely on local circumstances and finance. And although it must be remembered that more accurate conclusions are to be obtained from a few measurements of a large number of individuals than from a large number of observations on a few individuals, the value of a survey would be increased in proportion as a schedule containing a larger number of observations were generally adopted. The Sub-Committee is of the opinion that the teachers, with a little practical instruction, would be capable of making and recording the necessary measurements. In addition to actual measurements, careful note should be taken of the general physical condition, and a record of average (not record) performances in athletic sports and of proficiency in games should be kept.

In the case of the psychological observations the conditions are somewhat different. They would necessarily extend over a more or less lengthy period, and therefore should, if possible, be entrusted to the teacher. Graduated schedules for use in schools have not yet been drawn up, but the teachers—who, it must be remembered, at any rate in the elementary schools, have received some training in the observation of the psychical characters of childhood—may select for themselves from the schedule tentatively suggested by the Psychological Sub-Committee the characters with which they feel themselves most competent to deal.

With regard to the record of observations, unless a special inquiry is necessitated by local circumstances, some uniform system should be adopted, and the method of envelopes and cards suggested in the previous year's Report, which includes a record of family history, seems most desirable.

To secure the full value of the records a central body should be established upon which should devolve the comparison and statistical treatment of the observations made. Its duties should include the determination of average values, standard deviations, and correlations in different conditions; and when this has been done, the reporting the results of an examination of the material submitted to it to local education authorities and others interested.

SCHEDULES.

Schedules may be in card form or a number of schedules may be bound in book form. In some cases it may be found convenient to enter the measurements as they are made on cards, and afterwards enter the results in a book, each volume of which should contain material which is as homogeneous as possible, *i.e.* of the same age, class, &c.

Schedules will vary in complexity according to the number of data to be collected about each subject.

Annexed is a schedule suitable for entering perhaps the minimum useful number of data, but which is sufficient for the present requirements of the Board of Education This schedule may be printed on a card, with one corner bevelled off to facilitate putting it in the correct position in the box or drawer. Any special data about the individual or his environment may be entered on the back of the card.

*No.*______

*Name (in full)*______

*Sex*______

*Age*______

*Weight*______

*Stature*______

*Hair-colour*______

Results of Medical Inspection:

______

______

*Place of Observation*______

Signature of Observer and Date:

______

______

Cards of children of the same age should be preferably kept together.

Where time is available for making more measurements they should preferably be added in the order given in the following list :—

1. Stature.
2. Weight.
3. Hair colour.
4. Eye colour.
5. Chest (circumferences).
6. Chest (diameters).
7. Head length.
8. Head breadth.
9. Shoulder breadth.
10. Breadth between trochanters.
11. Height of head.

For example, if it is decided to measure four dimensions on each subject, the first four in the above list should preferably be selected, and so on.

A schedule in which provision is made for entering any number of the characters specified in this Report may be printed on a card preferably in the form shown below :—

A.D. ______ *No.* ______

Age ______

Surname and Christian Name (in full) ______

Sex ______ *Birthplace* ______ *Calling* ______

Father—
Birthplace ______
Calling ______

Mother—
Birthplace ______
Calling (if any) ______

Brothers : Nos. of Schedules ______ *Sisters : Nos. of Schedules* ______

First Cousins : Nos. of Schedules ______

No. in family and position of subject ______

Place of Observation ______

Signature of Observer and Date ______

Front of Card.

Anatomical Characters.		Physiological.		Psychological.	
(A 1)		(1)		(1)	
(A 2)		(2)		(2)	
(A 7)		(3)		(3)	
&c.		&c.		&c.	

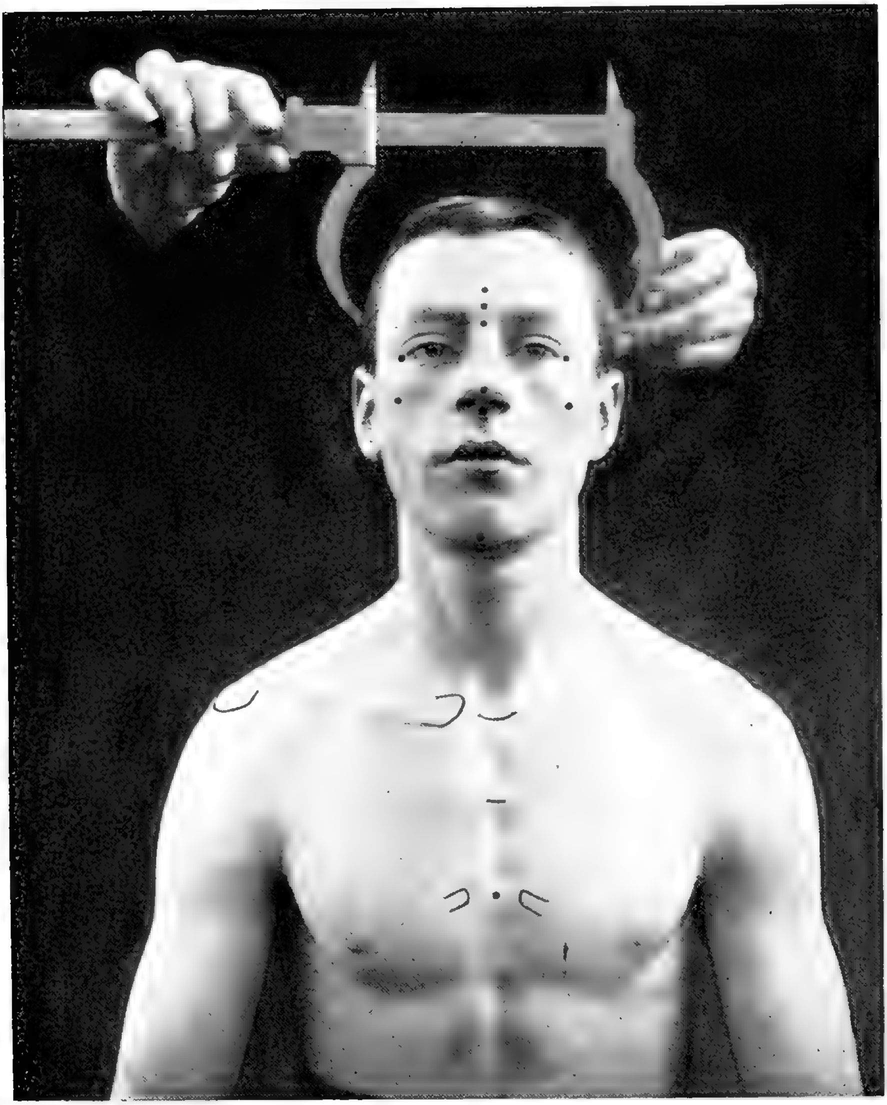
Back of Card.

	Environment.	Results of Medical Inspection.
(1)		
(2)		
(3)		
(4)		
&c.		
—		Miscellaneous Data.
—		

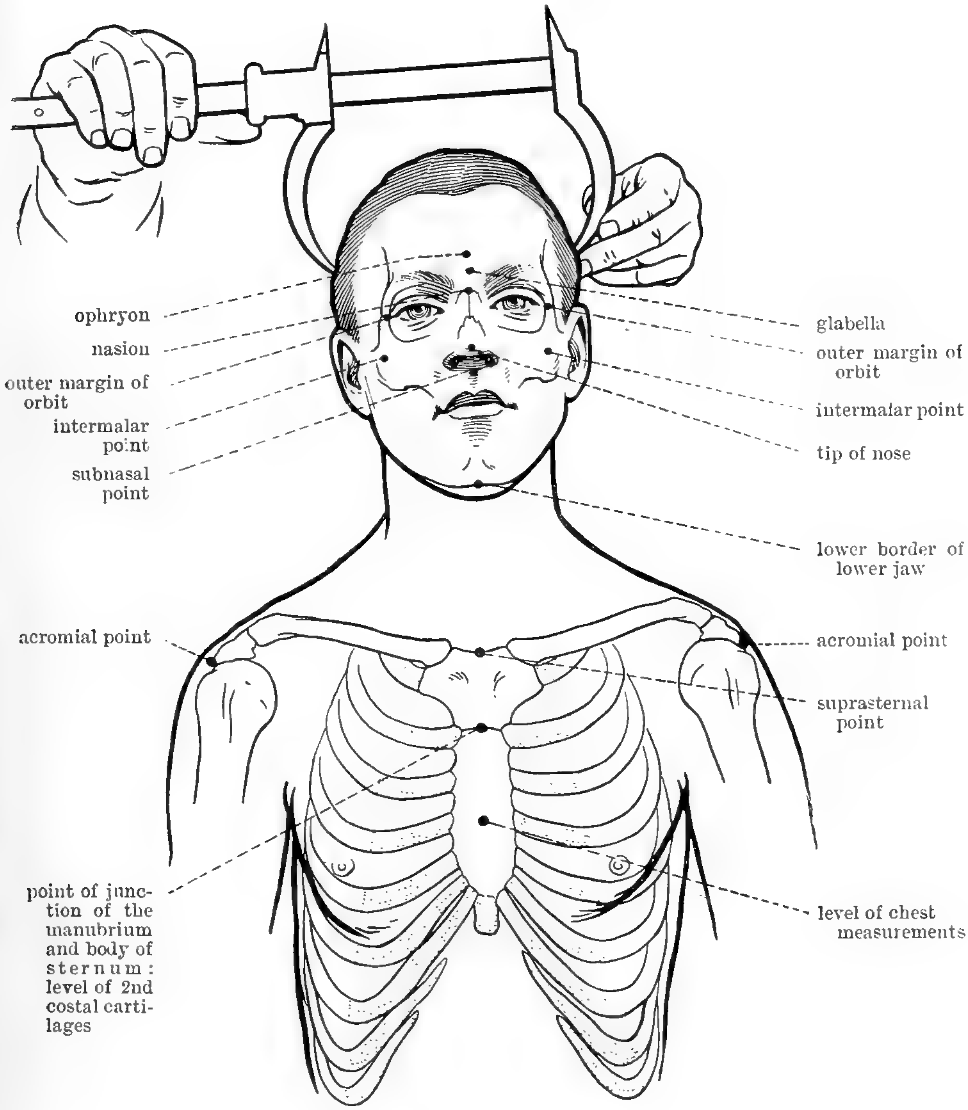
The symbols in the above schedule are given as examples merely, and represent the symbols denoting character in the lists given in this Report.

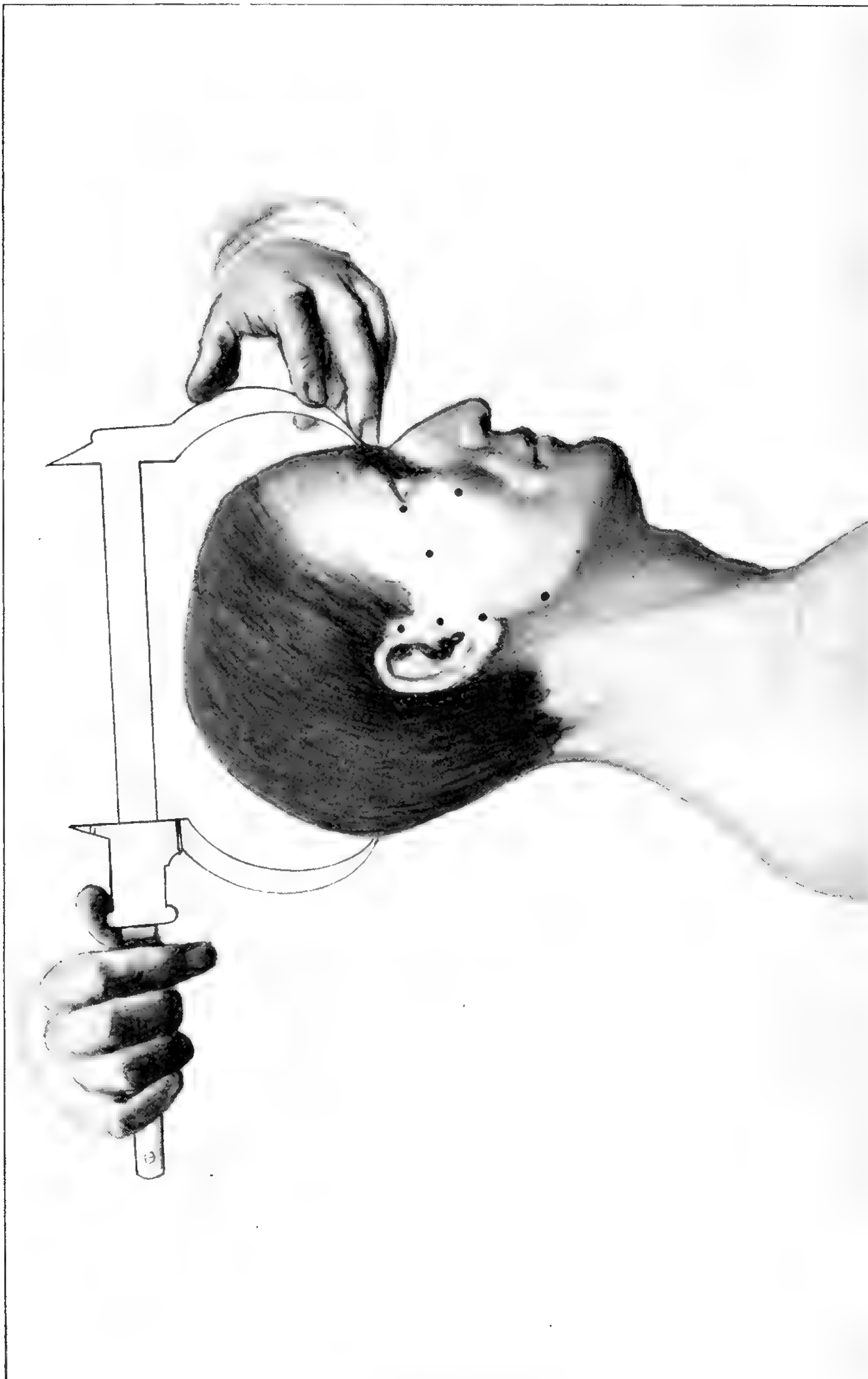
Any selection of characters may be made in accordance with the object of the special investigation. These characters should be denoted by symbols which may be used in the schedules, instead of the full name of the character, when it is desired to save space, and keep the schedule card or sheet as small as possible. One or more cards, if necessary, may be used for one subject.

Schedules of the above kind are very conveniently bound in book form. In this arrangement it is convenient to have a number of sheets at the commencement of the volume for general notes, say, on environment or other data that apply to all the individuals entered in the volume.



Front View of Head Chest and Shoulders (Cunningham).





Profile View of the Head (Cunningham).

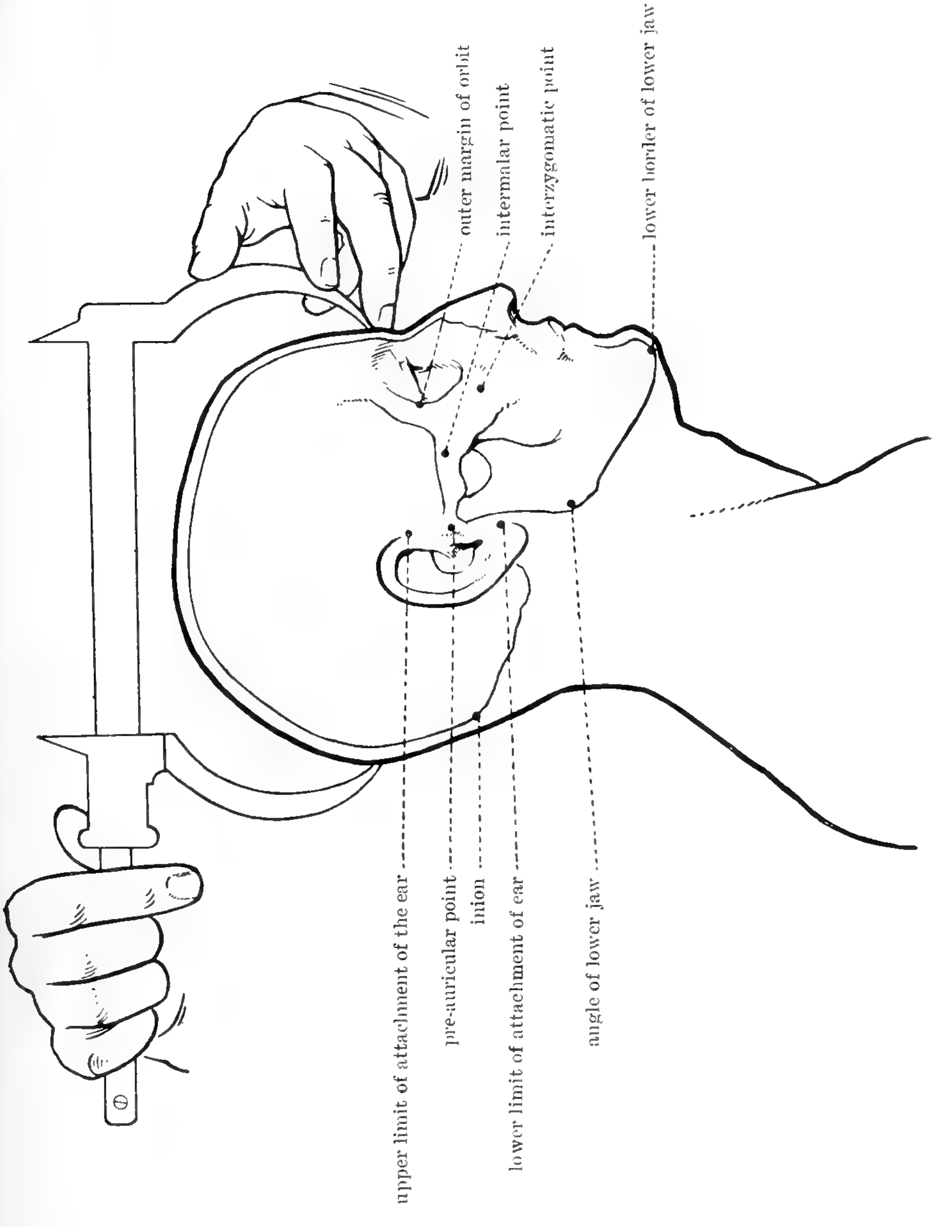
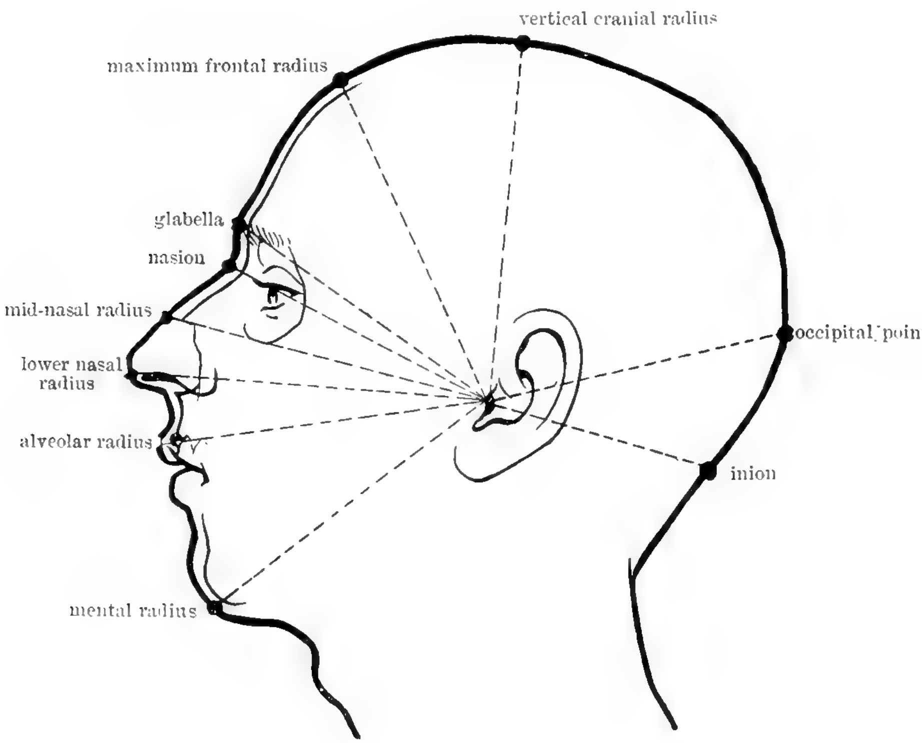
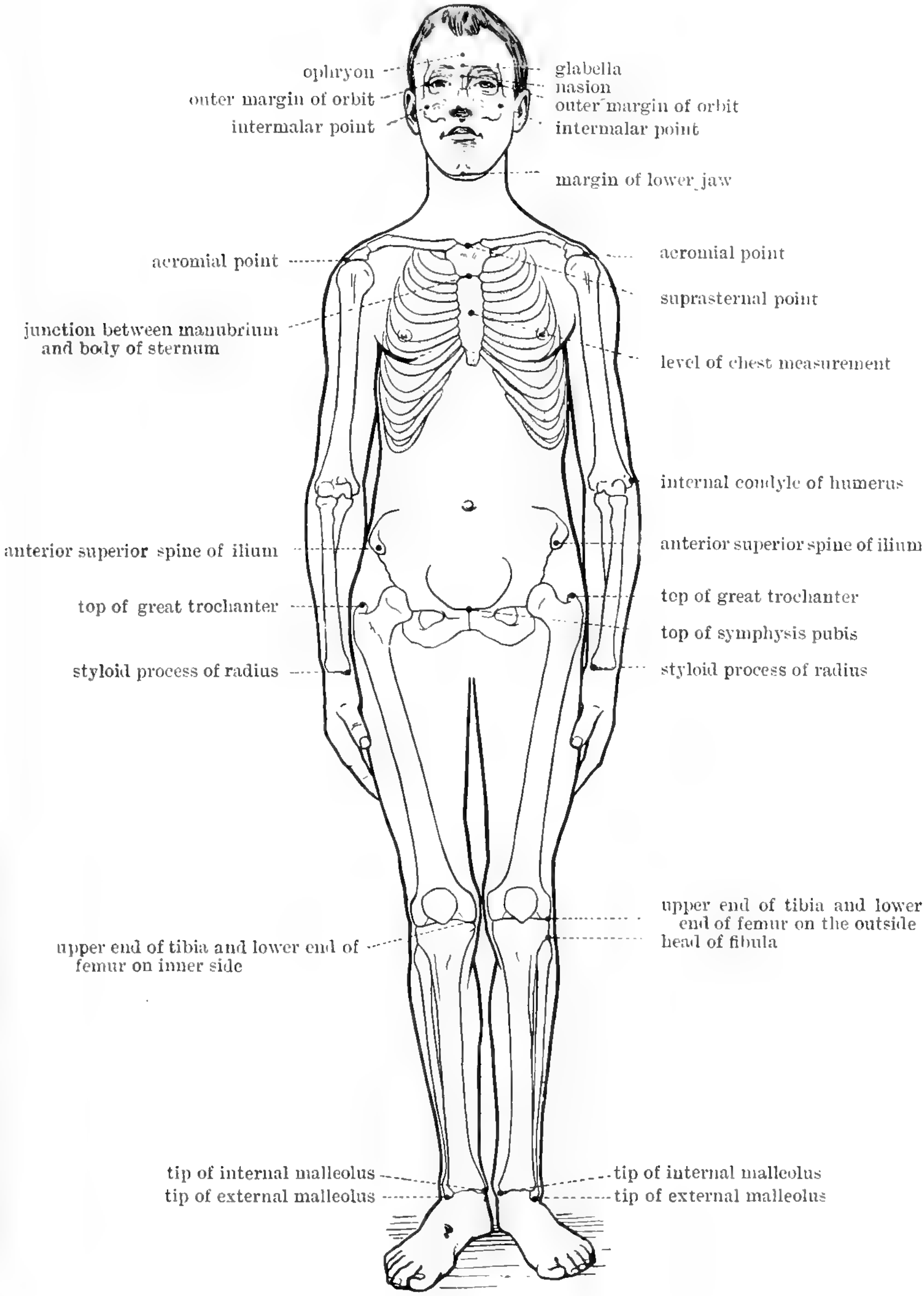


Diagram of Cranial and Facial Radii (Cunningham).

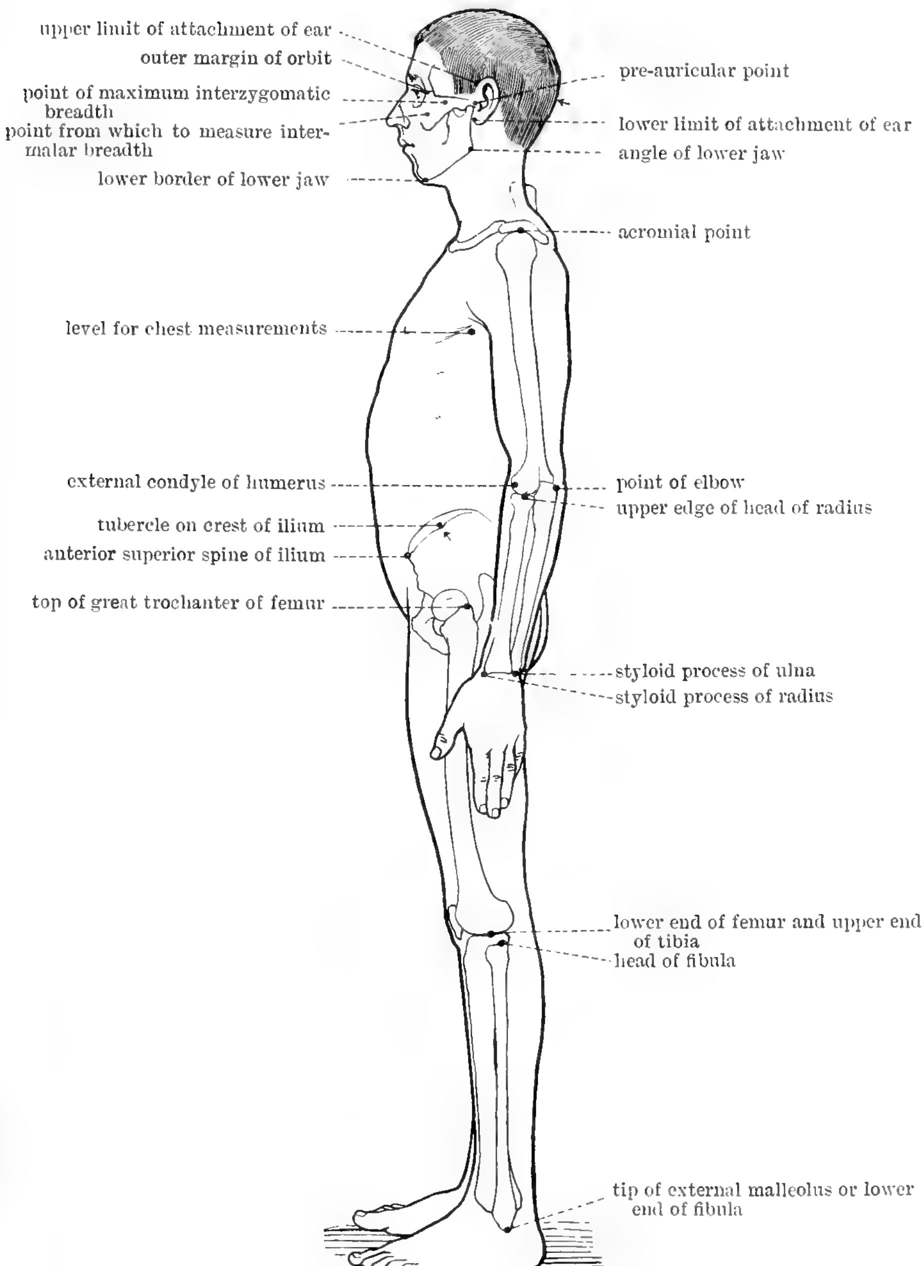
(The radii diverge from the centre of the ear-hole.)

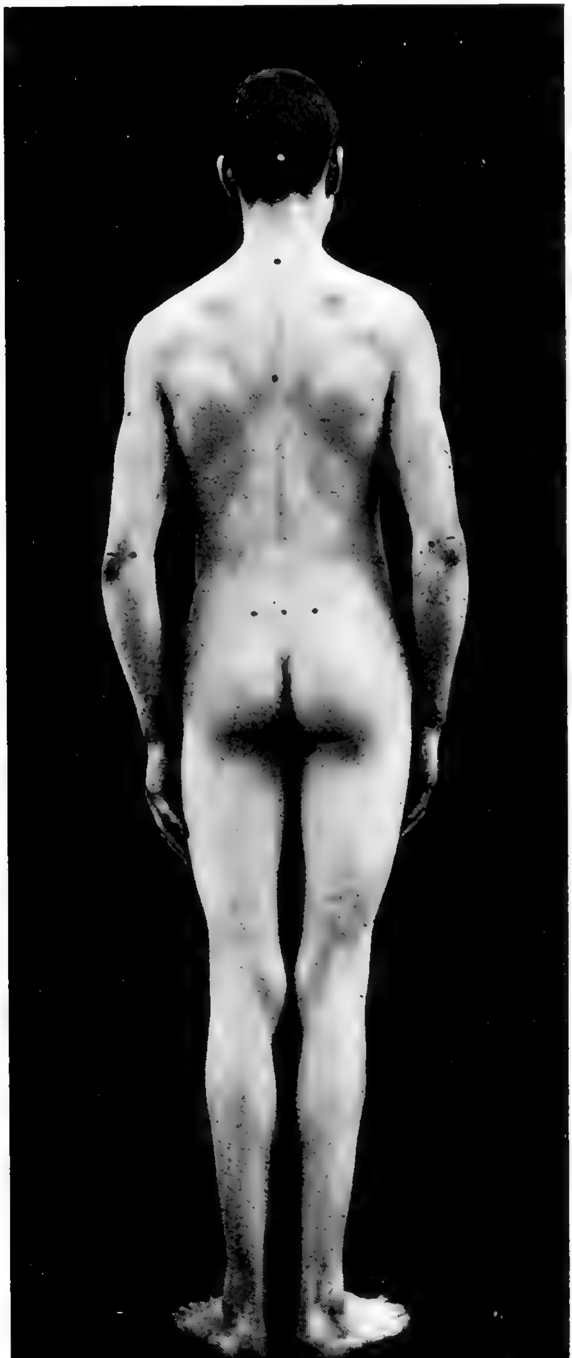


Front Aspect of Male Figure (Cunningham).

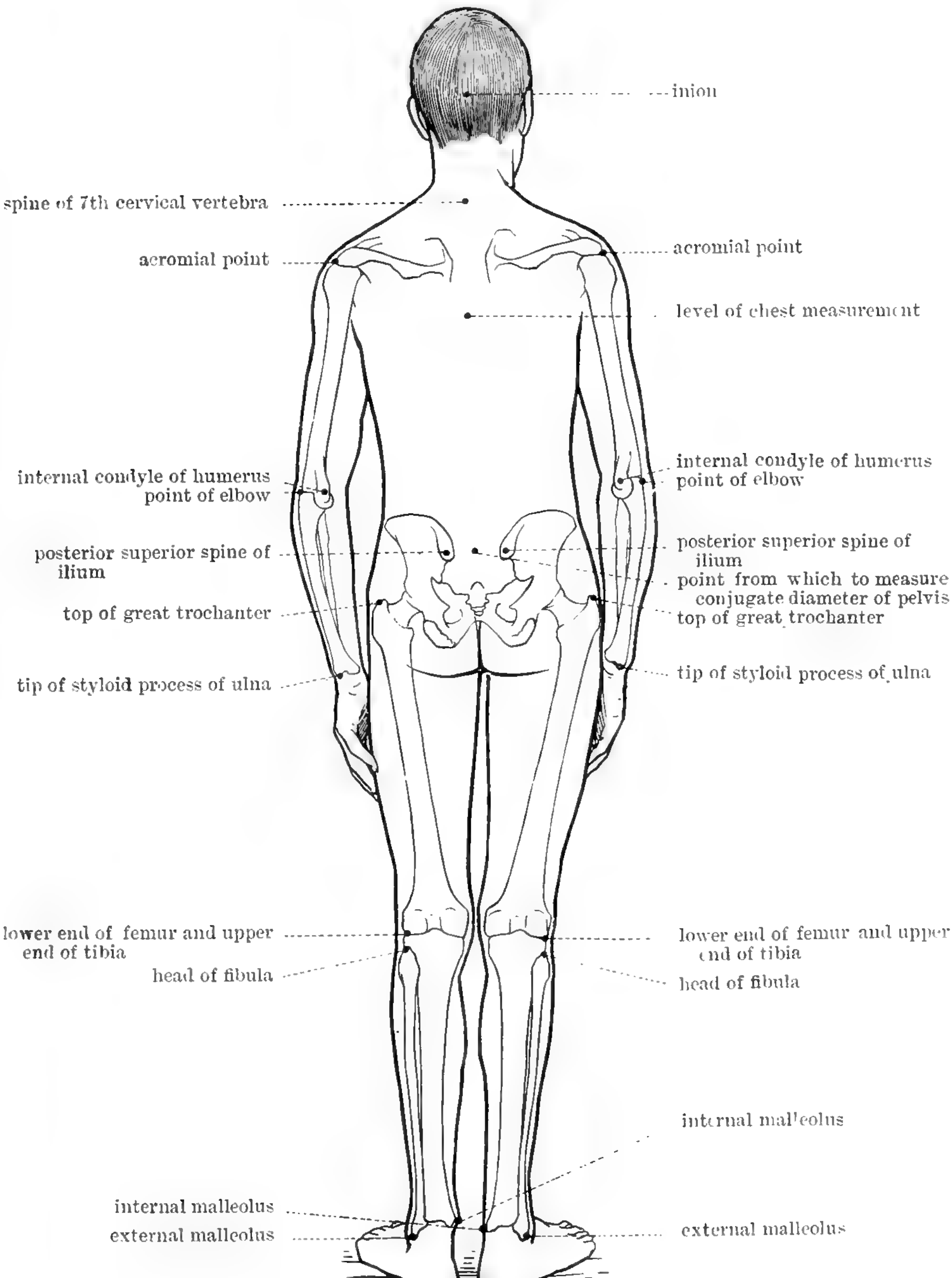


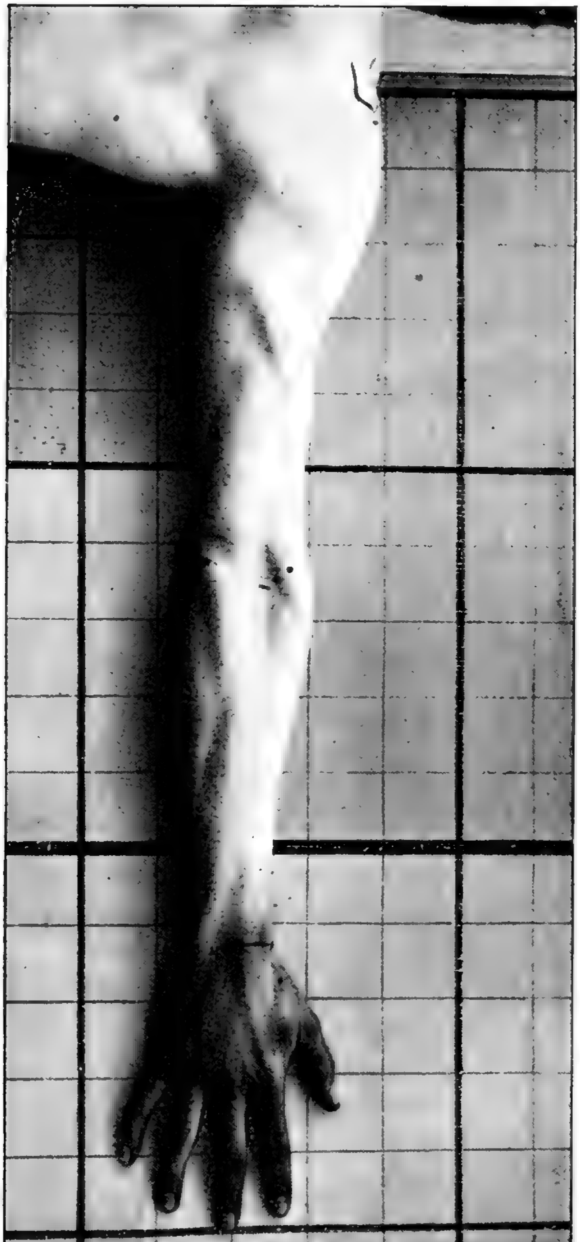
Left Lateral Aspect of Male Figure (Cunningham).



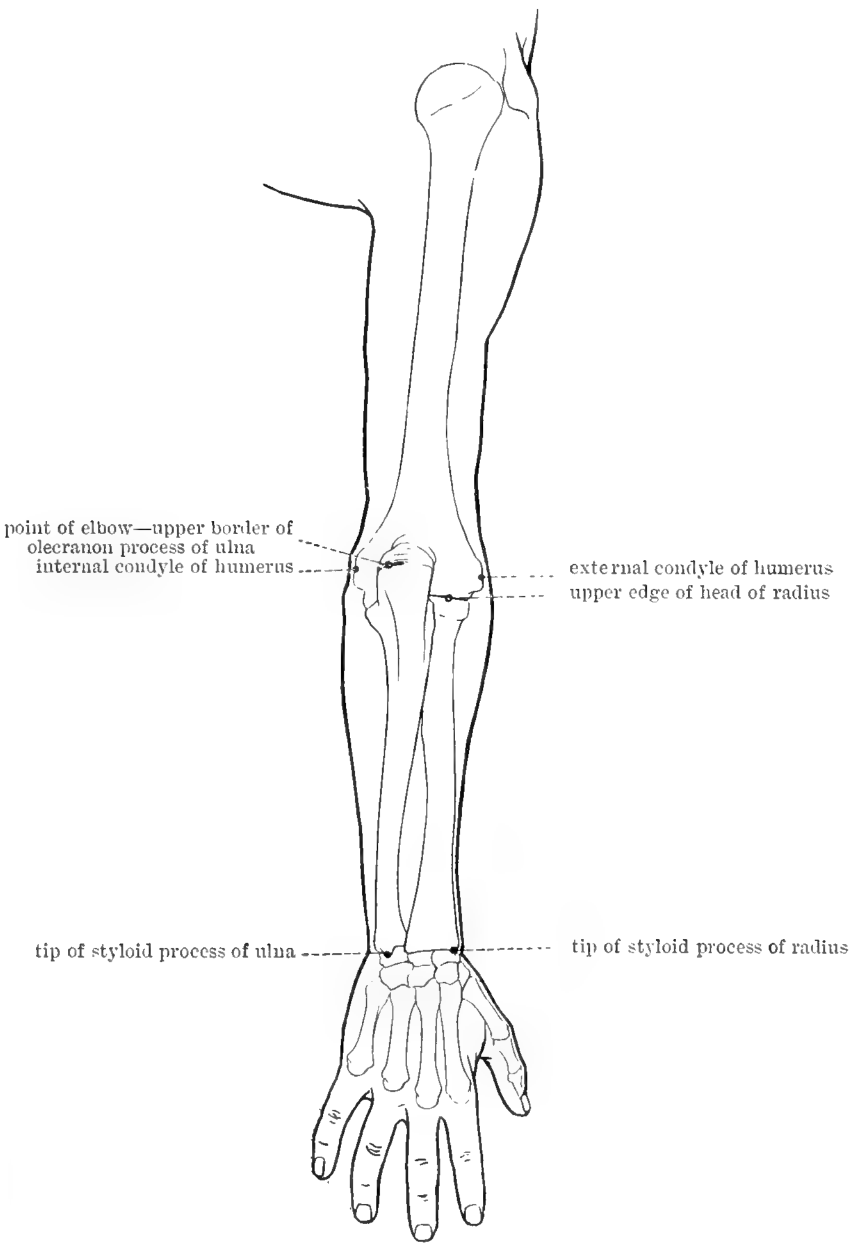


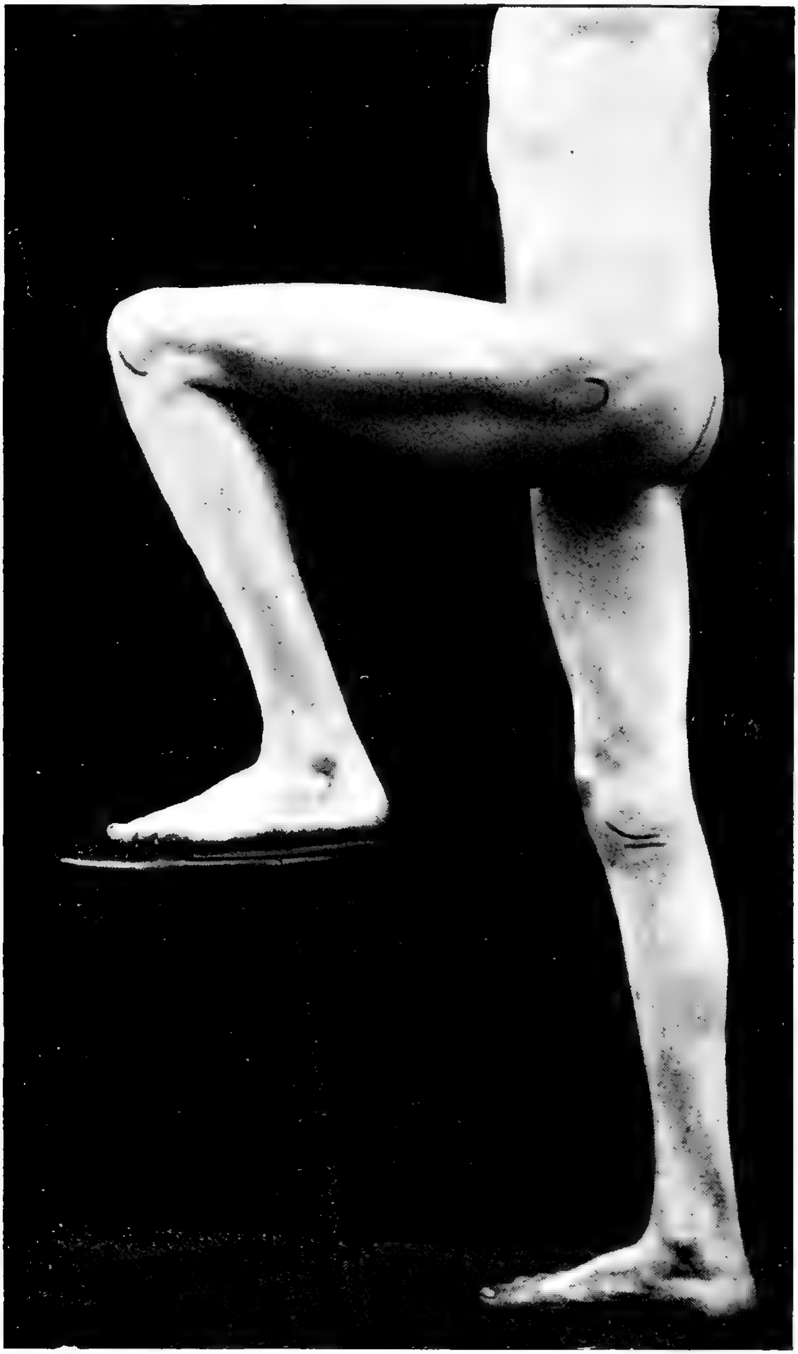
Back View of Male Figure (Cunningham).



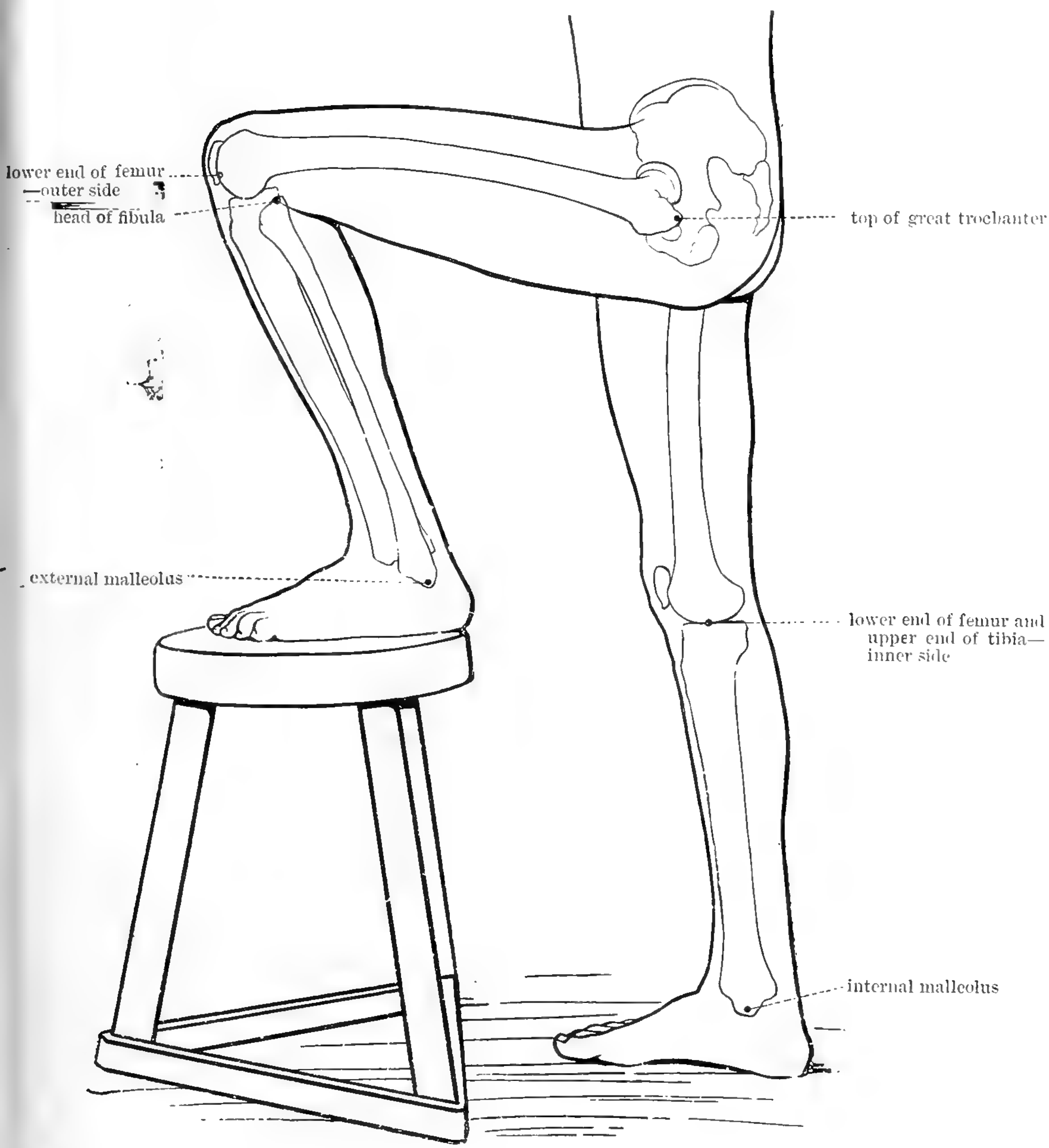


Posterior Aspect of the Fully Extended Right Arm (Cunningham).





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*), LORD AVEBURY, 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.*

THE Committee report that they have been able to carry out the plan of making excavations at Avebury, on the portion of the monument belonging to Lord Avebury, who kindly gave the necessary permission. The Committee in their last report asked for a larger grant than usual, owing to the size and importance of the work, and it has been found that the conditions were even more exacting than was foreseen. Owing to the great scale of the vallum and fosse, and more especially from the unexpectedly great depth of the latter, only a small section could be entirely explored. The small portions investigated have, however, yielded interesting results, though the evidence is not so conclusive as the Committee had hoped.

The most remarkable feature in the exploration was the great depth of the fosse. Before the original bottom was reached nearly 17 feet of silting had to be removed, and as the fosse at this point was about 35 feet wide at the surface of the silting and 17 feet wide at the bottom, and the cutting 24 feet long, the quantity of soil to be removed involved a very serious outlay. The section exposed showed very clearly the stratification of the silting. The relics found were few, but they bore out the theoretical chronology of the filling in of the ditch. At the bottom, practically on the floor of the fosse, were found picks made from the antlers of red deer, showing signs of use ; while at higher levels were found fragments of Bronze Age pottery, above these Roman fragments, and in the upper layers Norman and more recent relics. The deerhorn picks recall the flint mines at Cissbury and Grimes Graves, where similar picks were found in the workings and clearly belonged to Late Neolithic times. All that can be said at present is that the relics tend to confirm the theory that the circle at Avebury is of the Neolithic or Early Bronze period : but this can hardly be said to be proved by the present exploration. It is of the greatest importance, however, that an effort should be made now to decide this question definitely, and the Committee feels very strongly that the explorations at Avebury should be continued.

The Committee have been fortunate in again securing the services of Mr. H. St. G. Gray, who has superintended the workmen with his usual thoroughness ; he has made careful scale drawings of the sections exposed, and a series of photographs of the cutting at different stages of progress. Mr. Gray's detailed report is appended.

The Committee desire to thank Lord Avebury for kindly allowing the explorations to be made, and their thanks are also due to the Vicar, the Rev. J. G. Ward, for his services in securing labourers.

The Committee ask to be reappointed with a grant of 120*l.*, and with permission to accept contributions towards the cost of exploration from other sources.

The Avebury Excavations, 1908. By H. St. George Gray.

I. *Introductory Notes.*

In point of size and grandeur Avebury [1] stands out pre-eminently among the prehistoric stone monuments of Great Britain; at the same time it is decidedly difficult to realise fully what Avebury and its appendages were when in the height of their glory. The monument has been terribly mutilated, and vandalism must have reigned supreme for many years to effect the complete destruction of some 95 per cent. of the great monoliths. To understand the original form of Avebury it is necessary to refer to the plans of Aubrey, Stukeley, Hoare (drawn by Crocker), and Lukis. Modern archæologists can accept only a certain proportion of the statements and theories advanced by the earlier of these antiquaries. Much remains to be proved with regard to the precise original form of the great Avebury monument, and although the Kennet Avenue,[2] approaching Avebury from the S.E., is not disputed by anybody, antiquaries are still divided in opinion on the question of the former existence of a 'Beckhampton Avenue' on the W.S.W.[3] Then,

[1] 'Averberie' in *Domesday Book.*

[2] Of the Kennet Avenue nineteen stones remain, viz. eleven in a group half way between Avebury and West Kennet (which I photographed recently); one on the brow of the hill on the other side of the main road and towards Avebury; one close to the turnpike-gate outside the vallum; two stones on the Avebury side of West Kennet, between which the main road passes; and four in the bank on the left-hand side of the road from Marlborough as it enters West Kennet, which can be seen by going into the adjoining field. Stukeley, with Lord Winchelsea, counted seventy-two stones of this avenue in 1722. The eleven stones mentioned above average 70 feet apart, and the only remaining standing stone is 8 feet 9 inches high.

Stukeley records that two prostrate stones of this Avenue (destroyed in 1722) existed in the gap by which the Kennet road enters Avebury. Aubrey, in his plan (1663) shows seven stones immediately outside the gap through the southern vallum. Sir Norman Lockyer (*Nature*, Jan. 16 and Feb. 20, 1908) believes that the vallum of Avebury was raised long after the circles had been constructed, at a time when this Avenue became useless for astronomical purposes. He regards the Kennet Avenue as being made for the purpose of watching the rise of α Centauri (previously to 4,000 years ago), as a warner of the Nov. festival (while the sunrise in May was provided for in the Beckhampton Avenue). He goes so far as to suggest that the stones of the Kennet Avenue close up to Avebury may have been removed when the vallum was built! (For further information see *Nature*, and *Wilts Arch. Mag.*, xxxv. 1908, 515–7).

[3] In the *Guide to the British and Roman Antiquities of the North Wiltshire Downs*, the Rev. A. C. Smith has collected together the opinions of early writers as to the former existence, or non-existence, of the so-called Beckhampton Avenue. After mentioning Aubrey's absolute silence on the subject, he quotes the words of Stukeley at some length; then follow extracts from Thos. Twining, Jas. Fergusson, and the Revs. C. Lucas, Bryan King. and W. C. Lukis.

'There is no question that, if Stukeley's word is to be believed, he most certainly *saw* many sarsen stones lying in two, more or less apparent, lines west of the great circle of Abury: moreover, he speaks of ten stones of this Avenue known to have been standing within memory, between the exit of the Avenue from the vallum and the brook.' (Smith, 147.)

The Rev. Bryan King said: 'There are very few lineal yards which are not occupied by causeways, walls and cottages, all formed of sarsen stone, sufficient, and more than sufficient, to absorb all the stones of the Beckhampton Avenue.' (*Wilts Arch. Mag.*, xviii., 377–383.) Sir Norman Lockyer has dealt with the alignment of the Beckhampton Avenue in *Nature*, Jan. 16, 1908.

Nearly a mile to the S.W. of the centre of Avebury is the 'Longstone Cove,' or 'Long Stones,' also known as the 'Devil's Quoits.' Aubrey spoke of three upright stones, but two only remained in Stukeley's time.

again, the connection, if any, which Avebury had with Silbury Hill[1] remains yet to be determined. But the excavations recently conducted at Avebury were carried out, not to attempt to prove the above-mentioned points, but to endeavour to increase our knowledge with regard to the probable date of construction of Avebury, and to test the hypothesis put forward so often, that because the sarsens of Avebury are entirely unworked, the monument must be of earlier construction than Stonehenge with its dressed stones.

The Avebury of to-day consists of a few enormous standing stones and similar prostrate stones, scattered over an area which is usually recorded as 28½ acres and is surrounded by a stupendous fosse, now to a large extent silted up; this again is bounded by a vallum of imposing height, of which more than three-quarters remain, many parts being well preserved. The mutilation of the bank and ditch was caused chiefly by the building of the village and the construction of roads which approach the ancient monument from four directions. Walls and houses, obviously built of the venerable stones cracked up for the purpose, meet one's gaze at every turn. Indeed, as Lord Avebury has said in 'Prehistoric Times,' 'the pretty little village of Avebury, like some beautiful parasite, has grown up at the expense, and in the midst of the ancient temple.'

Aubrey,[2] Stukeley, and Hoare all agreed that a circle of stones followed the course of the fosse on its inner side, and that there were two smaller circles within the greater—one north and one south—each of which, according to Stukeley, contained a concentric circle; that in the centre of the N. ring there was the so-called 'Cove,' and in the middle of the S. circle a central monolith (according to Stukeley only). There is now no trace of concentric circles.[3] Stukeley's and Crocker's plans give the diameter of both circles as 410 feet, whereas Lukis

[1] Silbury Hill is on the N. side of the main Bath road between Calne and Marlborough, at a distance of 4,750 feet from the centre of the Avebury large circle, in a direction slightly W. of S. It is the largest artificial mound in Britain, having an average perpendicular height of 125 feet; its diameter at base is from 552 to 555 feet; circumference at base about 1,660 feet; angle of elevation, 30°.

Stukeley, in his work on 'Abury,' published in 1743, says: 'In the month of March 1723, Mr. Halford ordered some trees to be planted on the top of Silbury Hill, in the area of the plain 60 cubits in diameter. . . . The workmen dug up the body of the great king, there buried in the centre, very little below the surface.'

In 1777, a shaft was sunk from the summit by the Duke of Northumberland and Col. Drax. It is to be regretted that no detailed account of these operations is upon record; all that is known was published by Douglas in his *Nenia Britannica*, p. 161. In 1849 the base of the mound was tunnelled from the western 'isthmus' on the S. side of the hill. Two pieces of red-deer antler were found, and on the old surface fragments of a sort of string of two strands, each twisted. Vertebræ and ribs of oxen (? red-deer) and a large tooth were also discovered. It is recorded that the Royal Archæological Institute came across the shaft, 5 feet × 4½ feet, previously sunk from the summit of the hill, as before mentioned. (*Proc. R. Arch. Inst.*, Salisbury vol., 1849, see papers by Dean Merewether and C. Tucker, 73–81 and 297–303.) Excavations were conducted at Silbury Hill in 1867 to ascertain the direction taken by, and the position of, the Roman Road with relation to Silbury Hill. (See Preb. Wilkinson's paper, *Wilts Arch. Mag.*, xi. 113–118.)

[2] The stones of Avebury were first noticed by Aubrey in 1648–9.

[3] Of the N. inner circle, Sir R. C. Hoare's surveyor (Crocker) marked one stone as remaining in 1812, and Dean Merewether testifies to the existence of two prostrate stones in 1849. (A. L. Lewis in *Journ. Anthrop. Inst.*, 1891.)

says the N. circle was not more than 270 feet and the S. circle 320 feet in diameter.

Avebury has a circumference (according to Smith and others) of no less than 4,442 feet; whereas the vallum and fosse at Stonehenge measure only 1,107 feet in circumference, curiously enough, almost exactly one quarter of Avebury. Again, the diameter of the area at Avebury within the encircling vallum measures 1,400 feet, whereas that within the vallum at Stonehenge measures but 300 feet.[1] The average height of the central area of Avebury above mean sea level is 525 feet. It is, like Stonehenge, commanded by higher ground at a short distance off.

W. C. Lukis's plan, in Smith's large book on North Wilts, is probably the best as yet existing, showing the remaining stones and the probable position of others as ascertained by probing; also the position of holes which existed (some still exist) in the central plateau enclosed by the fosse. From it we find that in 1881 fifteen stones were still standing, sixteen prostrate stones remained visible, the existence of eighteen others, now buried underground, was ascertained, and thirty-three pits were observed in which stones formerly stood. Thus Lukis and Smith accounted for eighty-two stones altogether. The sarsens of Avebury are far larger than those of Stonehenge.

Avebury is one of the few stone circles where the ditch is within and the rampart outside. Other instances of this design occur at the following circles:—Arbor Low Derbyshire (already excavated);[2] the Stripple Stones, Cornwall (also excavated);[3] Stennis and the Ring of Brogar, in the Orkneys; and Arthur's Round Table, in Cumberland; also at Chlorus' Camp, N.E. of Salisbury.[4] At Stonehenge the shallow fosse is outside the feeble vallum.

II. *Previous Excavations.*

Avebury has been the site of archæological explorations on three former occasions, but in each case the relics appear to have been lost,[5] and very little indeed from the great 'Temple' is to be found in local or other museums.[6] In the first instance, excavations were conducted under the direction of the Wiltshire Archæological and Natural History Society in September and October 1865.[7] 'Considerable researches' were made by 'sinking holes in many places, running trenches across certain spots, and tunnelling the large external mound.' In the vicinity of 'The Cove,' within the N. circle, no traces of a burial deposit were found. It is stated that just under the turf two or three fragments of *British* pottery were found, together with bones of sheep and a small piece of burnt micaceous sandstone. In digging close to the two large stones of 'The Cove,' layers of blocks of sarsens, up to a size of 18 inches

[1] These measurements are not mine, but taken from various authorities.

[2] *Archæologia*, lviii. 461–498; *Brit. Assoc. Reports* 1901, 427–436, and 1902, 455–465; *Journ. Derbysh. Archæol. and N. H. Soc.*, xxvi. 41–77.

[3] *Brit. Assoc. Reports*, 1906, 370–382; *Archæologia*, lxi. p. 1, *et seq.* (not yet published).

[4] Hoare's *Ancient Wiltshire*, vol. i. 217.

[5] Since writing this the pottery found in 1881 has been sent to me for examination from Devizes Museum.

[6] In a fuller account of the Avebury excavations I hope to give a list of 'finds' previously made at or near this ancient monument.

[7] *Wilts Arch. Mag.*, x. 209–216.

across, were uncovered ; 'they were evidently placed there, and rammed in for the purpose of propping the massive stones in their upright position.' 'Black charred matter' is recorded to have been found, and numerous chips of sarsen. It was thought that fires had been lit here for the breaking up of the stones. 'A good deal of *British* pottery and many animal bones were found in these holes, but no human bones whatever.' To the S.E. of 'The Cove' a low embankment was cut through from W. to E., the 'finds' being a portion of a stag's horn and some fragments of pottery. An excavation was also made into the W. face of the E.N.E. vallum, but nothing was found. Another was made on the S.W. at a place where the vallum had been mutilated for the requirements of the modern village ; only one fragment of pottery was found here. A third excavation into the vallum was made to the W.N.W. side of the W. gap without any result in the way of relics. The excavations made in all numbered fourteen, and the fragments of pottery brought to light from the deeper cuttings 'were invariably of the British type.' This latter remark is vague, and without seeing the pottery it would be unsafe to regard the shards as all being of the Bronze Age. Some Norman pottery, although much harder baked, has often, in its coarseness and texture, much about the same appearance as ancient British pottery, containing grains of quartz, &c., and it is only during the last decade or so that we have been able to identify shards of pottery with any degree of certainty. Those responsible for the excavations of 1865 claim to have fairly upset James Fergusson's view that Avebury was a vast graveyard, and that human bones would be disinterred if search were made.[1]

When the Rev. W. C. Lukis was making a plan [2] of Avebury in 1881, his colleague, the Rev. A. C. Smith, rector of Yatesbury, resolved to examine the ground with a hope of discovering some buried stones. This was carried out by five workmen, and the spots specially observed were the places where Stukeley and Aubrey showed that stones had stood. The result was that sixteen large sarsens of the outer circle were discovered, some buried at a considerable depth. It was Mr. Smith's opinion that these stones had been sunk deep in the ground by means of pits dug beneath them, doubtless to be no longer a hindrance to the plough or for other agricultural reasons. They were covered up again after Mr. Lukis had made his plan, the spots being marked by numbered pegs, which have probably for the most part now disappeared. Lukis and Smith also noted and planned several pits in which stones originally stood. Hoare noted eight of these depressions, but Smith and Lukis were able to add twenty-five others not previously recorded. Smith did not find many relics during the work of 1881, but some of the pottery was, I believe, regarded as being of early date.[3]

In July 1894 excavations were made into the vallum and fosse on the S.E. at the expense of the then owner, Sir Henry Meux, Bart., under the general direction of Mr. E. C. Trepplin, steward of the estate, and

[1] Fergusson's *Rude Stone Monuments.*

[2] This plan is Plate V. in Smith's *Guide to the British and Roman Antiquities of the North Wilts Downs.*

[3] Since writing this report I have had sent me by the Wiltshire Archæological Society for examination fifty fragments of pottery found by Mr. Smith in 1881, and now deposited in Devizes Museum. All of the shards appear to me to be post-Roman, mostly of Norman date. There is certainly no fragment among them that can be regarded as pre-Roman. It is all of the same general character as the pottery found in my excavations in the S. fosse *above* the depth of 4·5 feet from the surface.

the immediate supervision of Mr. Thos. Leslie, also one of the officers of the estate. The 'finds' consisted mostly of fragments of pottery, one or two worked bones, a few flint implements, animal bones, and red-deer antlers, some bearing evidence of having been used as picks. The latter were found in the vallum, having been thrown up in a damaged condition at the time of their being broken—viz. when the ditch was originally being excavated and the vallum built. The fosse, apparently, did not yield any important results, as the excavations were carried only to a depth of 7½ feet from the surface of the silting (about the depth at which I came to the upper margin of the chalk rubble in the middle of the S. fosse). It would appear, therefore, that when the white chalk rubble (in fairly large knobs) was reached, it was thought to be the floor of the fosse. Mr. Leslie speaks of Romano-British pottery, which may probably be correct for the fragments found towards the bottom of his ditch-digging, but he does not appear to have dug more than a foot or so into the pre-Roman strata of the silting. He does not speak of Norman and Early English pottery in his notes, but those pieces found above 4½ feet in the silting would probably, on close examination, prove to be post-Roman shards. Perhaps the most interesting structural item revealed by the 1894 excavations was a possible indication of an inner mound, or vallum, subsequently surmounted by another vallum after the growth of vegetation on the presumably earlier structure. Mr. Leslie found the surface line of an inner bank defined by a curved band of vegetable mould measuring about 3½ inches thick. His rough notes are at present in my possession, and when a fuller illustrated account of the Avebury excavations is published, it is hoped that the 1894 digging may be spoken of at greater length. The drawings, relics, and full notes, over which Mr. Leslie, unfortunately, had no control at the close of the diggings, have been lost beyond recovery, it is feared, a fact which minimises the scientific value of those excavations very considerably.

III. *The* 1908 *Excavations.*

(a) *Prefatory Remarks.*—It was considered by the Committee that the fosse was more likely to furnish evidence of date than any other part of the Circles,[1] and a broad, well-preserved portion on the S., on Lord Avebury's property, situated about 156 feet W. of the Kennet Avenue entrance to this ancient enclosure, was therefore selected for the purpose of excavation. A considerable amount of surface silting appeared to have accumulated here, chiefly the result of road-dirt being drained into this portion of the fosse through the gateway on the high road. As one walks from the cutting to the gateway the silting naturally increases in depth. The part selected for digging was practically level from N. to S., and then began to rise in a S. direction towards the crest of the vallum, and in a N. direction towards the level area on which the circles of stones stood. In most parts of the earthwork the surface of the silting, the escarp of the ditch, and the summit of the vallum combined, show an ogee outline, but the S.E. quarter of the vallum and fosse differed,[2] and the curve from the surface of the silting to the crest of the vallum is not a true ogee, as a berme, or terrace, exists at the base of the vallum and above the escarp of the fosse.

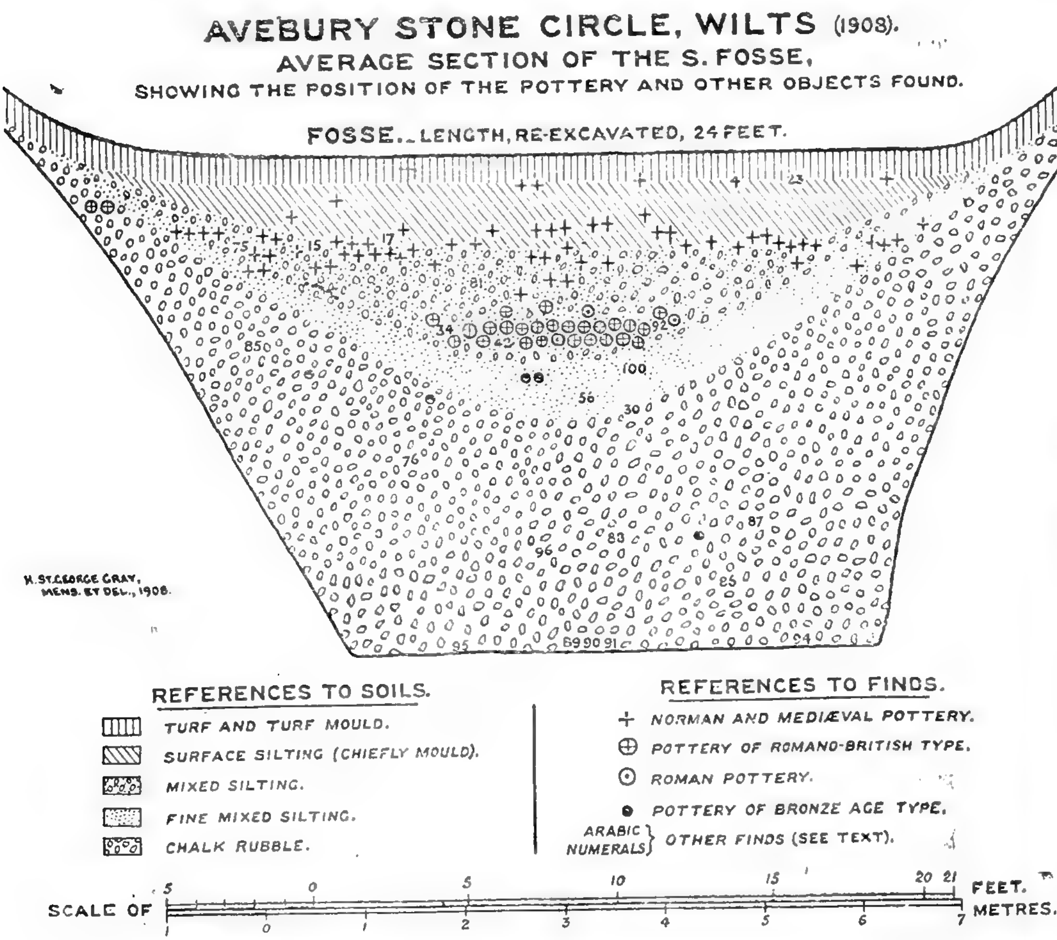
The excavations began on Tuesday, May 19, and continued till Saturday, June 6. The average number of men employed daily was nine, but for more than

[1] A preliminary inspection of the site was made on April 14, 1908, when Mr. C. H. Read (Chairman), Mr. Henry Balfour (Secretary), Mr. A. L. Lewis, and Mr. —St. George Gray met at Avebury.

[2] Where Sir Henry Meux's excavations took place.

half the time eleven men and a boy were engaged.[1] Only three-quarters of a day was lost owing to wet weather. Of both the cuttings sectional diagrams were made on the ground, plotted to a scale of 8 feet to an inch, in which the various soils were shown, and the exact position of every object of importance found during the excavations was projected into these sections, notes being preserved relating to each numbered 'find.' The accompanying diagrammatic section of Cutting I. shows the position of the pottery and other objects found, and the various strata which formed the accumulated silting in the fosse.

Sixteen satisfactory photographs (half-plate) were taken of Avebury, the majority showing the progress made in the excavations from time to time as new features presented themselves.



The excavations were visited by several fellows of the Society of Antiquaries of London, and by members of the Wiltshire Archæological Society, Somersetshire Archæological Society, and the Viking Club.[2]

After consultation with Lord Avebury it was decided to leave the excavations open until next spring, and a strong stake and wire fence has therefore been erected to enclose the disturbed ground.

[1] Most of the men were local labourers, but I brought with me, as foreman, T. Paul, of Glastonbury, for many years engaged in work at the Lake Village there, and another man with similar experience.

[2] The Chairman and Secretary of the Stone Circles Committee, British Association, visited the excavations, and Lord Avebury came down from London on two occasions.

(b) *Cutting I., Fosse.*—This cutting was 24 feet long, the most westerly margin being about 156 feet from the middle of the hedge along the road at the Kennet Avenue entrance. Turf was removed to a width of 26 feet in the first instance, but this dimension in some places had to be increased to 45 feet in order that the profile of the fosse, when partly re-excavated, might be shown to better advantage.

In plotting the sectional diagram it was found that the present surface of the silting of the fosse in this part was approximately 14 feet lower than the original ground level above it (viz. the level of the adjacent field in which the remains of the outer circle of stones are to be seen) at the time of the construction of the fosse. It is rather remarkable that the Avebury fosse has not silted up to a greater extent.[1]

As it was anticipated that the fosse might prove to be deep, ledges had to be left in the silting at different stages to allow of the material being thrown up from the lower levels with comparative ease; and it was found necessary in a large cutting of this sort to wheel out nearly all the material on planks.

The turf and turf-mould was found to reach to a depth of 0·8 foot; in it several modern shards and scraps of iron were found. We next came to a fine gritty mould, which has been called 'surface silting.' The average depth of this in the middle was 3·3 feet from the surface, tapering off towards both sides of the ditch. In removing this layer horizontally we, of course, came to earlier deposits *on the sides*, viz. mixed silting and chalk rubble. As will be seen by the diagram, the strata are deepest in the centre of the fosse, the surface of each deposit, as viewed from above, presenting a decidedly concave outline. The deeper a ditch, the more pronounced one expects to find this characteristic. Silting falling into an open ditch from either side naturally covers the sides very rapidly, and the surface of the silting as it increases from bottom to top is always concave, more so in the early stages of filling than later.

The next deposit—mixed silting, consisting of mould with a larger proportion of small pieces of chalk—extended to an average depth of 8·7 feet in the middle of the silting. This deposit was also on the curve. In most places the bottom 2 feet of this silting was found to be of a finer kind with a smaller admixture of bits of chalk, and it is differently represented in the diagram.

When the middle of the mixed silting was reached we proceeded to trace the hard chalk walls of the fosse on both sides to the depth we had excavated. This done, the work from day to day became temporarily checked by the caving-in of parts of the vertical face of the silting, sometimes two or three tons falling in one night. This is well seen in the photographs. In the mixed silting, at depths of 5, 6·3, 6·3 and 7 feet respectively, four sarsen boulders were found, each about 2 feet across.

The mixed silting proved to be an interesting deposit as far as fragments of pottery were concerned. Four distinct qualities were found, representing three definite archæological types. In the upper third, and *above* a depth of 4·5 feet from the surface, Norman and Early English pottery was found commonly, indicating not only that Avebury was overrun during those times, but also that since early Norman times about 4·5 feet of silting had accumulated in this part of the fosse. Secondly,

[1] I heard some reports that the fosse had been cultivated as arable land some five or six decades ago, but I was unable to substantiate those statements on making inquiries from old inhabitants.

pottery of the Roman period was found at depths varying from 5 to 6 feet in the middle of the mixed silting deposit; and thirdly, two fragments of coarse British pottery of Bronze Age *type* were found in the lowest third of the mixed silting at a depth of 7·2 feet from the surface. In the middle division of this area twenty-five fragments of pottery were collected, all of Romano-British type and unornamented. Some of the pieces were small, and it is possible that a few of them may be post-Roman, but all undoubtedly are pre-Norman. The three pieces of Roman ware associated with the Romano-British pottery consisted of a very thin fragment, brick-red on the two surfaces (No. 80), a large piece of painted New Forest ware (No. 98), and a piece of tile, *tegula* (No. 24). The coarse Bronze Age *type* of ware, containing large grains of quartz, survived into Roman times, and is occasionally found with Romano-British shards. But when found in deep deposits, unassociated with Romano-British pottery, it is generally safe to regard it as being of Bronze Age manufacture. In the Avebury fosse, however, the highest pieces of the early type are found 1·2 feet below the Romano-British type. The position of the various qualities of pottery in the mixed silting was most satisfactory as regards chronology.

To complete the account of the pottery from Cutting No. I. we must at once turn to the vast accumulation of chalk rubble, from 8·7 feet below the surface of the silting to the bottom of the fosse. The only fragments of pottery found in this deposit were three small pieces of Bronze Age ware, at depths of 7 feet, 7·8 feet, and 12·5 feet respectively, two being of the coarsest description.[1] There is no question about the depth of this last-named fragment, which was found in my presence by the foreman (who did all the important digging at low levels).

With one exception, the other 'finds' in the chalk rubble were valueless as evidence of date. But that exception was an important one, viz. the finding of five red-deer antler picks (Nos. 89, 90, 91, 94, and 95), for the most part fractured and incomplete, but capable of considerable repair,[2] resting on the solid chalk floor of the fosse—thrown away when they became useless as tools. One or two of these picks prove to be excellent specimens; with one exception they are shed antlers, two being extremely massive. (For details, see Section f.) It is difficult to realise how this stupendous fosse was excavated out of the solid chalk by means of antler picks only. There can be no doubt, I think, that the hardest chalk must have been loosened, at least to some extent, by the blows of flint hammers and mauls.[3] The other appliances used in this work would probably be wooden and bone shovels, and baskets and ropes to haul the chalk to the surface. Close to the bottom of the ditch we found a fragmentary shoulder-blade bone in a very bad state of preservation, but I was unable to determine if it had been used as a shovel ('Archæologia,' xlv. 345).

A flint knife was found at a depth of 13 feet and worked flint flakes at 7·3 and 10 feet; also a piece of human skull-bone at an approximate depth of 12 feet. The relics are referred to later.

[1] Two fragments of Romano-British pottery were found in the chalk rubble, but quite high up, *close to the inner wall* of the fosse, and as evidence of date their position was unimportant.

[2] They have been restored by Mrs. St. G. Gray.

[3] In some cases the blunt end of the picks appears to have been used for hammering.

The chalk rubble covered the sides of the ditch up to the top; in the middle of the silting the deposit was reached at a maximum depth of 8·7 feet, and extended downwards to the floor of the fosse to a maximum depth of 16·8 feet, and a minimum depth of 16·6 feet, from the surface. We were much impeded in clearing the smooth, flat floor of the fosse owing to the repeated falls from the vertical face of the silting. However, after perseverance, a length of 17 feet was cleared at the bottom,[1] the length of the excavation on the surface being 24 feet. The bottom of the fosse averaged 17 feet in width (between 17·3 and 16 feet in one part). The inner wall of the fosse did not vary in slope very considerably, as seen by the diagram (inclination about 59°), but the lower 5 feet of the outer wall was very steep in most places (maximum inclination 80°). No tool-marks were observable on the walls of the fosse, near the bottom or elsewhere.

(c) *Cutting II., Fosse, and digging to the East of it.*—At 87 feet to the W. of the hedge of the road coming into Avebury from Kennet, and at 69 feet to the E. of the W. margin of Cutting I., another section was surveyed across the silting of the fosse. On May 23 a large cutting was begun here. It was soon found that as this section was nearer the road there would be a greater amount of surface silting to remove than in Cutting I. At the bottom of the surface silting several fragments of Norman and mediæval pottery, two flint flakes, and a core were found, but as time pressed (Cutting I. having proved a heavier task than was anticipated), it was found necessary to cease working at Cutting II. on June 1, hoping that it might be completed at some future time. A total depth of 5·5 feet was attained on the W. and 5 feet on the E. Present length of the cutting 9·5 feet. Judging from the sides already exposed, it appeared possible that the fosse might be narrower at the bottom as it approached the Kennet Avenue entrance.

If at no other place, it is quite reasonable to suppose that the 'Temple of Avebury' was entered from the S. by way of the Kennet Avenue. We should, therefore, look for an entrance causeway in the position of the modern road and a little to the E. of Cutting II. Indeed, this cutting was commenced here in order that it might be prolonged eventually in search of the end of the fosse terminating in a solid chalk causeway. To try and prove the existence of such a termination on the S. we made several trial-holes to ascertain the direction taken by the upper margins of the walls of the fosse exposed in Cutting II. Holes were made along both margins, and in all those nearest to Cutting II. the solid chalk upper margin of the fosse wall was revealed; but, instead of the fosse narrowing, it widened as it approached the hedge and road. A trench was dug on the S. side up to the hedge, and on the N. side close to the gate, but without proving that the fosse rounded off. If such a termination does occur under the W. side of the roadway, then the solid chalk entrance must have been narrow for so important a monument as Avebury. On the other hand, there may have been no entrance causeway, and it is possible that the fosse was spanned by a bridge. It is feared that, owing to the presence of the hedge and modern roadway, it may be difficult to prove the point. The best course to pursue would probably be to continue Cutting II. towards the hedge, and, if found necessary, to drive a tunnel under the road at a safe level.

(d) *The Silting in Cutting I.* (*see Sectional Diagram*). *Dimensions taken in the middle of the silting.*—1. Turf and turf-mould, thickness 0·8 foot.

2. Surface silting, average thickness 2·4 feet; fine loamy silt of light-brown colour, without lumps of chalk, washed in and partly the result of denudation, but mostly derived from silt drained into the fosse from the roadway.

[1] On a future occasion the remaining seven feet length of chalk rubble could be excavated in the hope of finding other relics in this important deposit.

3. Mixed silting, average thickness 3·8 feet, consisting of rather darker loamy mould than the surface silting, and containing a fair proportion of small lumps of chalk from $\frac{1}{4}$ inch across to about 2 inches. On the W. side of the cutting a hard band of lumps of chalk was noticed across the middle of this stratum. Some of the lumps were 3 or 4 inches long, and resulted from a sudden fall of chalk from the profile of the fosse. This layer, 2 inches thick, was so hard that the foreman thought at first that the bottom of the fosse had been reached.

4. Fine mixed silting, average thickness 2 feet. A narrow, curved layer, consisting of fine chalk mixed with a small proportion of light yellowish-brown loam or mould.

5. Chalk rubble, average thickness 7·8 feet. The upper layers of this deposit consisted of rather small lumps of chalk seldom more than 3 inches across, and usually much smaller. Some of the pieces were found agglutinated as if by the lime contained in water which had percolated through the silting. The lumps of chalk were larger towards the bottom. Occasionally thin curved seams of mould were observed in this deposit, caused by the falling of turf and mould from the margins of the open fosse as it was gradually widening and falling from natural causes, or by the deposit of surface mould thrown up undesignedly during the process of building the vallum.

(e) *Other Notes on the Pottery.*—Every fragment of pottery found in Cutting I. is projected into the sectional diagram accompanying this Report, the different qualities being represented by symbols to show their relative depth at a glance. The position of each fragment was carefully marked, as discovered, in the sectional diagram, and the classification which was subsequently added was made quite independently of the depth at which it was found.

The five pieces of early British pottery of Bronze Age type, found at depths varying from 7 feet to 12·5 feet, consisted of one smooth fragment containing fine grains of quartz (the No. 4 British quality of Pitt-Rivers) and four pieces of ware, containing large grains of quartz, of the roughest description, and as rude as the piece of pottery found with the Stone Age interments in Wor Barrow, Handley.[1] (The latter, however, contained large grains of chalk and not quartz.)

The twenty-five fragments of Romano-British and the three pieces of Roman pottery have already been briefly described in Section b. It remains, therefore, to say something with regard to the shards of Norman and mediæval pottery, which, taken as a whole, are typical of the period. This pottery bears a very close resemblance, both in quality, form, and general character, to that found by me in the great camp of Castle Neroche, seven miles S.S.E. of Taunton.[2] The trained eye has no great difficulty in distinguishing between mediæval and pre-Norman pottery, although it is true that 'puzzles' occasionally crop up. Norman pottery was comparatively plentiful in the upper strata of the silting of the fosse, indicating probably a large population at Avebury during that period. Among the shards are a large proportion of pieces of rims and bottoms of vessels; less frequently handles of pots were found, and fragments bearing definite traces of glaze.

(f) *Other Finds, Cutting I.* (*see numbers in Sectional Diagram*). *Flint Implements.*—42. Long knife with dorsal ridge slightly worked along both edges, with evidence of prolonged use. Depth, 6·3 feet in the chalk rubble.

76. Large worked flake. Depth, 10 feet in the chalk rubble.

81. Large rough scraper-shaped flake. Depth, 4 feet in the mixed silting.

85. Flake worked to a bevelled edge along one side. Depth, 7·3 feet in the chalk rubble.

96. Finely worked knife (the only well-chipped implement found). Depth, 13 feet in the chalk rubble, and within 4 feet of the floor of the fosse.

In addition, four large pieces of flint, bearing signs of slight rough flaking and hammering, were found in the upper strata of the fosse. Of flint flakes, unworked,

[1] *Excavations in Cranborne Chase*, iv., plate 257, fig. 19.
[2] *Proc. Som. Arch. Soc.*, xlix., part ii., pp. 23–53.

the following were gathered:—In the surface silting, down to 4 feet, 8; in the mixed silting, down to 6 feet, 26; and in the chalk rubble, down to 15 feet, 30; total, 64.

Iron Objects.—15. Two oblong-headed horseshoe nails, depth 2·8 feet, at the top of the mixed silting. Another was found at No. 99 in Cutting II., depth 3 feet.

17. Part of a horseshoe, depth 2·7 feet.

56. Mediæval arrowhead with socket of circular section; shank nearly straight and bevelled abruptly near the point, where the cross-section is rhombic; length 1¼ inch. Viscount Dillon, F.S.A., writes thus: 'The Avebury specimen is a mediæval arrowhead of the "pile" class, and for use with the long bow. It is an interesting and rare example, but the actual date is quite uncertain."[1] The workman (W. Smith) who found this arrowhead at a time when I was engaged in drawing, assured me that it was dug out of the fine mixed silting at a depth which I found to be 7·8 feet from the surface. It is quite probable that a small pointed object like this might work its way down from its original position in the silting by means of rabbit and other holes to a much lower level. On the other hand, as the workman had just begun a fresh 'spit,' earth containing the arrowhead may have fallen from a higher level beforehand without revealing the object. However, No. 56 is shown in the diagram at the depth at which it was picked up.

75. Tang and portion of the blade of a small knife, found at a depth of 2·8 feet in the mixed silting.

Pieces of iron slag were found in the upper strata down to a depth of 4·5 feet.

Miscellaneous Objects.—4. Farthing of William III., 1698. Depth 1 foot at the top of the surface silting.

23. Piece of stone fractured through an artificial perforation. Depth 0·8 foot at the bottom of the turf mould.

A small Jacobean clay pipe was found at a depth of 1 foot.

Human Remains.—Fragmentary human remains are frequently found in the excavating of ditches, and indeed in most ancient sites. Four instances occurred during the digging of Cutting I. at Avebury, viz.:—

30. Part of the lower jaw of an adolescent with two well preserved molars. Depth 8·3 feet in the chalk rubble.

34. Greater part of a left clavicle (least circumference 36 mm.). Depth 5·7 feet in the mixed silting.

87. Fragment of skull-bone (probably parietal). Depth 12 feet in the chalk rubble.

100. Part of a right temporal bone (petrous and mastoid portions).[2] Depth 7 feet in the chalk rubble.

Picks of Red-deer Antler, &c.—Perhaps the most interesting 'finds' from these excavations are the picks of antler found on the floor of the fosse in five instances. All are marked in the diagram and are described below.

86. Greater part of a pick made from a shed antler of red-deer, the bez-tine broken off. Parts of the brow-tine are very much polished, the rounded point broken. This was not resting on the bottom of the fosse, like Nos. 89, 90, 91, 94 and 95, but at an approximate depth of 14 feet.

89. This is not the longest of the Avebury picks, but it is the most massive, measuring 219 mm. in circumference just above the burr, and 183 mm. round the beam between the brow- and the bez-tines. The stump of the trez-tine is seen, and close to it the handle terminates in a smooth bevelled end. The long brow-tine displays a graceful curve ending in a smooth point. The bez-tine is seen only as a stump. This was also a shed antler.

90. Fine specimen of a pick made from a large shed red-deer's antler. Present

[1] *Vide* also on mediæval arrowheads, *Gentleman's Magazine*, cii. 1832, part i., 114.

[2] Dr. W. Wright thinks it is that of a female adult, the extreme smallness of the mastoid process being due to sex.

length 22½ inches; maximum circumference of beam 140 mm. The brow-tine does not appear to have been utilised in this specimen, but is broken off short. The bez-tine is straight and at an angle of about 40° with the beam of the antler. The smooth rounded point bears evidence of considerable use. The stump of the trez-tine is rounded and very smooth. The end of the handle and the grip are much polished in places.

91. Pick formed from a large shed antler of red-deer. The bez- and trez-tines have been broken off. The brow-tine, which is set at a very obtuse angle with the beam of the antler, is much worn down from prolonged use. Circumference of antler just above the burr 200 mm.

94. Greater part of a pick of red-deer antler; of average size; much damaged; the brow-tine bears evidence of use.

95. Pick formed from an average-sized antler of a slain red-deer. The brow- and bez-tines are poorly developed, and both were probably used together as a double pick. The rounded point of the bez-tine is in good condition.

88. A few fragmentary pieces of red-deer antler; approximate depth from the surface 12·5 feet.

92. The burr, base, brow- and bez-tines of a small stag's antler, shed. The point of the bez-tine somewhat smoothed. Depth, 5·7 feet in the mixed silting.

An antler pick, much damaged, was found in the excavations at Stonehenge at a depth of 5·7 feet. It is to be seen in Devizes Museum.[1] General Pitt-Rivers found an antler pick of the Romano-British period at Woodyates (? Vindogladia); the handle end, as well as the brow-tine, was cut and rubbed.[2] A good specimen of an antler pick was exhibited by the Rev. Bryan King, vicar of Avebury, in 1880, on the occasion of the visit of the British Archæological Association to that place.[3] But the Neolithic flint mines of Grime's Graves and Cissbury have produced more specimens of these antler picks than any other places in Britain. At the Grime's Graves, excavated by Canon Greenwell, the picks were all found in the galleries or in the filling of the shaft, below 17 feet from the surface; the total number discovered was seventy-nine. Examples from the Grime's Graves,[4] Cissbury,[5] and from the flint mines at Spiennes, near Mons, Belgium,[6] are exhibited in the British Museum.

(g) *Animal Remains.*—Animal remains, mostly fragmentary, were found plentifully in Cutting I., and the maximum depth at which they were traceable (apart from the antler picks and the shoulder-blade before mentioned) was about 9·5 feet. In the surface deposits animal bone was quite plentiful, and the remains were found to be mostly those of young animals, the epiphyses being wanting. There has not been time to go into details with reference to these remains, but it is possible to record that the following larger animals are represented:—Horse, ox, pig, red-deer, roe-deer, sheep, dog, and (?) fox and wolf. The remains of oxen appear to have been most plentiful; the relative size of these bones varied considerably; a tibia found at a depth of 5·5 feet gives a height for the animal of 3 feet 2 inches, whereas a complete metatarsus (depth 6·5 feet) give a height of only 3 feet ¾ inch; from a metacarpus (depth 6·8 feet) a height of 3 feet 5½ inches was estimated. The ox was clearly traceable down to a depth of 9 feet, and remains apparently belonging to one animal were found at a depth of 8·8 feet; astragali and digits were quite plentiful. The horse remains, including many teeth, extended to a depth of at least 7 feet, and for the most part belonged to small animals. The red-deer was represented, in addition to the antlers, by an os calcis, astragalus, teeth, and small parts of lower jaws; the largest of the latter,

[1] Figured in *Archæologia*, lviii. 71.

[2] Figured in *Excavations in Cranborne Chase*, iii. 135.

[3] The Rev. A. C. Smith, in his large work, informs us that 'fragments of antler picks, the instruments with which the graves had been dug, have been found repeatedly in opening the barrows of North Wilts.'

[4] *Journ. Ethnol. Soc.*, 1870, n.s., ii. 426; and *Archæologia*, xlv. 342.

[5] *Archæologia*, xlv. 344; *Guide, Stone Age, British Museum*, 1902, 81.

[6] *Guide, Stone Age, British Museum*, 85.

however, was at a depth of only 2·5 feet. The roe-deer was represented by a piece of antler at a depth of 7 feet. The sheep jaws and other pieces were found down to 6 feet. Most of the pig teeth, &c., were found in the upper deposits, and the lowest depth appears to have been 6 feet. The dog was represented by lower jaws and bones varying much in size; some of the smaller may be remains of fox. The lowest dog bones were at 8·8 feet deep. A tibia, found at a depth of 5·5 feet, gave 1 foot 11½ inches for the height of the animal, and a humerus at about the same depth gave a height of 1 foot 9 inches.

(h) *Concluding Remarks.*—The excavations at Avebury, so far as they have gone, have given satisfactory and encouraging results; but the evidence of date is not strong enough to determine, with any degree of precision, whether the fosse and vallum were constructed in late Neolithic times or in the early Bronze Age; and we have not yet decided the relative dates of Stonehenge and Avebury—a matter of far-reaching interest and importance to the archæologist. The enormous fosse with its steep sides, great depth, and surprising width, is probably the largest ancient ditch in Britain that has ever been re-excavated. In the work of the re-excavation of the great ditch encircling the long barrow known as Wor Barrow, Handley, Dorset, it was found that the deepest part was 13½ feet below the silting. This was regarded as a stupendous undertaking; at Avebury, however, we had the task of removing 16¾ feet of silting before reaching the floor of the fosse.

No doubt the Avebury fosse increased in width a good deal, during the time that it was left open, to the bottom; but when allowed to fill up the chalk rubble must have accumulated very rapidly, probably in a period not exceeding fifty years. The relics found in this deposit, therefore, although it could not be expected that they would be numerous, are of the highest importance as evidence of date, not necessarily of the *actual* time of construction, but approximately of the time when the fosse was allowed to fill up from natural causes. After the profile of the fosse became covered with silting, the rate of filling would become very much slower and would advance in a decreasing ratio as time went on. Three fragments of pottery of Bronze Age type in the lowest deposit are not enough to base a sound conclusion on, and the few flint implements and human remains found there are not of a character to help us in the matter of date. But when antler picks were found on the floor our minds drifted back to late Neolithic times. At any rate until further excavations are conducted, we may rest assured that the fosse of Avebury was constructed in a late stage of the Neolithic or at the beginning of the Bronze Age, a period suggested by Lord Avebury many years ago.

The Lake Village at Glastonbury.—Tenth Report of the Committee, consisting of Dr. R. Munro (*Chairman*), Professor W. Boyd Dawkins (*Secretary*), 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 examination of the entire site comprising the Glastonbury Lake Village was completed in 1907, and during the past year an exhaustive description has been in course of preparation. Owing to the large amount of material, notes, plans, drawings, and photographs to be gone through and prepared—a collection that accumulated during the sixteen years the excavations were in progress—the work of compilation for publishing has been found somewhat onerous, but the chapters by the various contributors are now well in hand, and it is hoped the monograph will be published next year.

During the past summer tentative explorations have taken place at another Lake Village site at Meare, situated between two and three miles west of the Glastonbury Village.

The existence of this site has been known to Mr. Bulleid since 1895, but the Glastonbury excavations being in progress no examination was attempted until this year.

The Meare Lake Village lies on the peat moor to the north side of a low ridge of ground, on which the village of Meare is built, and from 400 to 600 feet south of the River Brue.

The tract of land in this neighbourhood was at one time occupied by Meare Pool, a body of water which in the early part of the sixteenth century was five miles in circumference. All traces of this lake have disappeared owing to drainage, and its position is now represented by fertile pastures.

The Lake Village consists of two distinct groups of circular mounds, **A** and **B**, separated by a level piece of ground about 200 feet in width.

The site covers parts of five fields, and measures some 250 feet in width N. and S., by 1,500 feet in length E. and W.

Group **A** occupies parts of three fields, and consists of some forty dwelling-mounds. This portion contains the more important mounds, the highest being 4·4 feet above the level of the surrounding fields. This is twice the height of the largest dwelling-mound excavated at the Glastonbury Village.

Group **B** represents at least fifty dwellings, together with the areas of ground between them. These dwelling-mounds are comparatively low, and range in height from a few inches to 2 feet at the centre, which is the highest part.

During the flood-time last spring the two areas of ground, **A** and **B**, were the only dry spots in this part of the moorland. The level of the land lying to the south of the village is only 13·6 feet above the mean tide level at Highbridge, 10 miles distant, and near the mouth of the River Parret. The flood-soil covering the fields immediately adjoining the village varies from 1 to 2 feet.

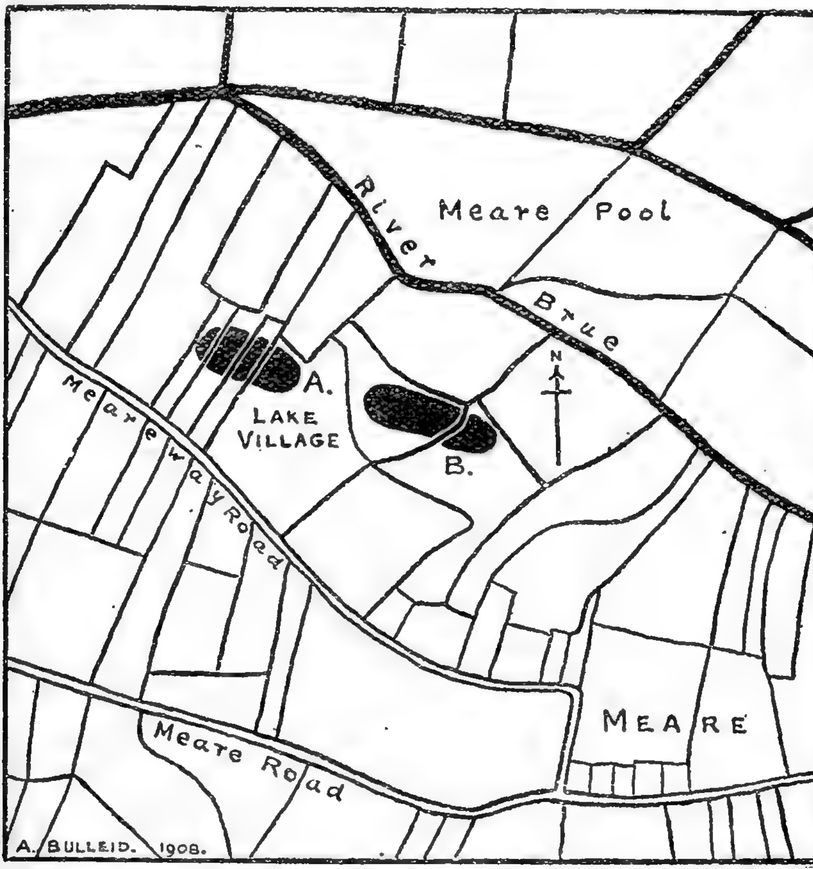
The recent trial excavations at Meare consisted of digging a trench 5 feet wide through the centre of a dwelling-mound of medium size, and two trenches in the level ground passing N. and S. of the dwellings in Group **A**.

The two latter were made with the intention of finding the boundary palisading, but although the ground was explored for more than 50 feet beyond the outside mounds, no protection-wall of posts was found; but the ground still produced pottery and other evidences of occupation.

Test-holes were also dug in two mounds in Group **B**.

The examination proved conclusively that both groups of mounds were constructed on similar lines to those at Glastonbury.

The section dug through the mound in Group **A**, provisionally called Dwelling-mound I., was of great interest, apart from the number of



objects it produced. The foundation consisted of eight clay floors, one above the other, together measuring 6 feet in depth, with twelve superimposed hearths. The greatest diameter of the mound was 32 feet N. and S. Below the clay floors was a substructure of brushwood and timber 2 feet in thickness, and under this the reeds and rushes forming the original lake-bed. The hearths were made of baked clay, with the exception of the lowermost, which was paved with a few small stones.

The actual size of the dwellings erected over the floors was not ascertained, but the walls had been constructed of wattle-and-daub, as proved by the fragments of baked clay found bearing impressions of wattle-work and timber, evidently the remains of a burnt habitation.

Considering the small amount of digging that was done, the 'finds' were exceedingly numerous, and the one small trench through this mound yielded more objects than were found in many of the largest Glastonbury dwellings. There were few spadefuls of earth that did not contain something of archæological value. Fragments of pottery and bones of animals alone filled several wheelbarrows. Considerably over one hundred rims of distinct pots and thirty pieces of pottery, ornamented with different designs, were found. Amongst the other objects of interest were the following:—

Amber. (A.)

1. Small red amber bead, showing considerable signs of wear; ext. diam. 12·5 mm.; diam. of hole 4·5 mm.; section oval. Only five amber beads and parts of beads were found in the Glastonbury Lake Village.

Bone Objects. (B.)

1. Distal end of a tibia of ox, cut off at right angles to the shaft at 82 mm. from the end

2. Two pieces of rib-bone with knife-marks.

4. Bobbin consisting of a metatarsus of sheep or goat, with condyle trimmed off at the distal end; at the proximal end there is the usual double perforation—at end and side. The wool, or other fabric, was drawn off these bobbins as required for the weft, passing through the holes to prevent the unrolling of the wound-on thread. Several dozens of these objects were found in the Glastonbury Village.

5. Pin showing considerable signs of wear; length 89 mm. It tapers from a max. diam. of 7 mm. at one end to the point at the other end, and has no perforation.

6. The greater part of a skewer made from part of the shaft of a tibia of a sheep (?) These objects were found commonly in the Glastonbury Village.

7. Metatarsus of sheep, highly polished; smooth transverse parallel grooves are observable in several places.

10 Part of a bobbin, polished, of precisely the same type as B 4 described above.

13. Two pieces of animal bone showing teeth-marks.

3. Shoulder-blade (*scapula*) of horse or ox, considerably worked and ornamented, and perhaps used as a shovel. At the articular end is a hole for suspension. The projecting anterior spine has been cut away; also the small coracoid process. The flatter face is ornamented by a line of large representations of the dot-and-circle pattern following the margin of the object, with an arm of the same pattern projecting inwards from each of the four sides. The circular grooves are large, measuring 9 mm. in diam., and they were evidently described by a pair of compasses, the dot representing the position of the stationary leg. Objects of this character were not identified at the Glastonbury Village. In the flint workings at Cissbury five scapulæ were found, three of which had the spines cut away. They were regarded as shovels; one has been figured.[1]

8, 9, 11, 12, and 14–18. Fragments of nine worked scapulæ, similar to B 3, but unornamented, four of which are perforated at the articular end. The spine in some cases is not completely cut down. Some of the specimens are much polished.

Baked Clay other than Pottery. (D.)

1. Triangular loom-weight of the usual Late Celtic type, with holes for suspension across two of the corners.

2. Grooved piece of baked clay of semicircular section. The groove has evidently been subjected to intense heat, and the object may form part of a mould for metal work.

3. Piece of wattle-marked clay.

4. Two pieces of a triangular loom-weight.

Five fusiform sling-bullets.

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[1] *Archæologia*, xlv. p 315. See also the Report on 'Avebury,' p. 406 *supra.*

Bronze Objects. (E.)

1. Small ring, band-shaped, with a central groove encircling it.
2. Piece of thin sheet bronze, shaped, and having one rivet-hole.
3. Another fragment, thicker, and triangular in form.
4. Spiral finger-ring of about $1\frac{1}{2}$ turns, composed of flat sheet bronze tape gradually towards both ends. It is ornamented with two encircling grooves hatching between. Int. diam. 18·5 mm.
5. Fragment of a finger-ring.
6. Piece of bordering for a sheath or other object; length 104 mm., average width 6·3 mm. It bears traces of having been ornamented with a zigzag linear design of a similar pattern to that seen on many of the weaving-combs of the period.
7. Three little pieces of bronze dross.

Flint. (F.)

1. Scraper with chipped and bevelled edge, of horse-shoe shape; length 34 mm.
2. Small elongated scraper.
3. Worked flake.
4. Long, narrow piece of burnt flint.
5. Three flakes and part of a calcined scraper.
6. Short knife of plano-convex cross-section, well chipped.

(*Glass.* G.)

1. Knobbed piece of pale peacock-blue coloured glass; length 12 mm.

Objects of Antler. (H.)

4. Cylindrical piece of polished antler, length 65 mm.; perhaps the handle of a tool; diameters 21 by 18 mm.

9. Awl-handle of antler, with remains of iron tang protruding from one end; length 63 mm. At each end there is a band of cross-hatching by way of ornament.

11. Greater part of a tine, smooth, and bearing saw-marks; length on the curve 160 mm.

12. Piece of antler with projecting tine, very smooth, and bearing indications of saw-marks and knife-cuts.

1. Weaving-comb, having eight teeth, tapering in length from one side to the other. They show the usual groovings and signs of wear. The shaft is highly polished, the ornamentation consisting only of two transverse lines at the base of the teeth. The handle-end has been damaged, and bears indications of having been gnawed. Length 114 mm.

2. Double-ended weaving-comb, much weathered and devoid of ornament. Very few combs of this type were found in the Glastonbury Village. Six coarse but complete teeth remain at one end; there were seven teeth at the other end, of which one only now remains complete. Length 186 mm.

3. The handle-end of a weaving-comb, found in four fragments, some being 5 feet apart. The handle of this comb was considerably curved. The ornamentation consists of a double zigzag pattern along the length of the handle similar to that on H 6 and E 6. Length of remaining part 113 mm.

5. Weaving-comb, repaired and now almost complete. Of the nine original teeth seven remain complete. Like H 1, they taper in length, although not to such a great extent. The handle is highly ornamented with zigzag grooves, four deep, extending from both sides and forming lozenge-shaped interspaces down the middle and triangles along the sides. The five lozenges are filled with single dots-and-circles measuring 11 mm. in diameter; the two side triangles nearest the handle-end likewise have the large dots-and-circles. Length 160 mm.

6. Handle of a weaving-comb which once had eight teeth. The butt-end exhibits signs of considerable wear. The ornamentation consists of a double zigzag pattern along the length of the handle similar to that on H 3 and E 6. Present length 138 mm.

7. Handle-end of a weaving-comb of very unusual form, the sides of the oblong enlargement (which sometimes occurs in these combs) being deeply notched on the curve. Double lines crossed occupy the two compartments marked off for ornamentation.

8. Parts of a weaving-comb of which the remains of five teeth are still seen; the handle much weathered; no ornament beyond a transverse groove indicating the depth to which the teeth were to be cut.

10. Weaving-comb having eight of its original nine sharp teeth remaining, which, like H 1, has longer teeth on one side than the other. The perforation for suspension is 6 mm. in diam. The ornamentation consists of a pair of transverse grooves at both ends of the shaft, with triple transverse grooves at irregular intervals between; two of the interspaces are partly filled by a single diagonal line. Length 140 mm.

Iron Objects. (J.)

1. Fragment, probably of a knife, covered with vivianite.
2. Two pieces of iron much corroded, of quadrangular section; probably the greater part of a Late Celtic door-key.
3. A large piece of iron band, or hoop-iron, varying in width from 40 to 50 mm., and having one circular perforation.
4. Five pieces of corroded iron, two of which may be parts of the key, J 2.

Kimmeridge Shale. (K.)

1. One-half of a lathe-turned armlet, which, when complete, was 92 mm. in ext. diam. Unornamented; section, oval, flatter on the inner than on the outer face.
2. Armlet (or anklet?), highly polished and lathe-turned. Ext. diam. 95 mm. (about $3\frac{3}{4}$ inches). It was split obliquely in one place when found; otherwise complete. The section of the shale is oval, flatter on the inner than on the outer face (dimensions 10·5 by 7·5 mm.). Two heavier shale armlets, with external diameters of 97 and 109 mm. respectively, were found in the Glastonbury Lake Village.

Animal Bones. (N.)

1. Metacarpus of sheep or goat, with an enlarged distal end, apparently the result of disease. The bone has been polished, and shows a transverse notching on both sides (with slight grooves—see B 7) near the large end.

2, 4, 5. Part of lower jaw with teeth and other bones of beaver. (Some of the bones, otter?)

3. Horn cores of *Bos longifrons*, goat and sheep.

6. Small lower jaw, *not yet identified.*

Pottery. (P.)

The pottery has already been spoken of at the end of Part I. of this Report. A large proportion of the fragments are ornamented with designs typical of the period, nearly all being represented in the Pottery Series from the Glastonbury Village. Similar designs have been found in Somerset, but much less frequently, on Ham Hill (near Stoke-under-Ham), at Worlebury and Cannington Park Camps, and in Wookey Hole. The fragments from Meare for the most part belonged to small vessels. One piece with a 'cordon' reminds one of the vases from the Aylesford urn-field.

Querns. (Q.)

1, 3. Upper stone of saddle-shaped querns.

4, 5. Fragments of lower stones of saddle-shaped querns.

2. Fragment of lower stone of round quern.

Stone Objects. (S.)

1, 15, 18. Hammerstones.

2–13, 16, 17, 19, 20. Whetstones, chiefly of sandstone.

14. Small thin disc of lias, with a perforation 11 mm. in diam.

21. Waterworn block of lias, with a chipped circular depression $3\frac{7}{8}$ inches in diam.

22. Piece of calcined (?) lias, with perforation.

23. Two small waterworn pebbles, perhaps used in games.

Tusks and Teeth. (T.)

1. Boar's tusk, with circular perforation (diam. 4 mm.) for suspension.

2, 4. Five other boars' tusks.

3, 5. Two teeth, pig and dog.

Spindle-whorls. (W.)

1. Large flat spindle-whorl of lias with irregular edge; diam. of hole 11 mm.
2. Oval sandstone disc, with incipient hole on one face, and probably a spindle-whorl in the process of manufacture.
3. Small, thick spindle-whorl of lias, with hole 8 mm. in diam.
4. Somewhat irregular baked clay spindle-whorl with perforation.
5. Thick stone spindle-whorl not truly circular, with perforation 5·2 mm. in diam.

Fragmentary oyster-shells, snail-shells, limpet-shells, and bits of calcined bone were also collected.

Anthropological Photographs.—Report of the Committee, consisting of Dr. C. H. READ (*Chairman*), Mr. H. S. KINGSFORD (*Secretary*), Dr. T. ASHBY, Dr. G. A. AUDEN, Mr. H. BALFOUR, Mr. E. N. FALLAIZE, Dr. A. C. HADDON, Mr. E. SIDNEY HARTLAND, Mr. E. HEAWOOD, Professor J. L. MYRES, *and* Professor FLINDERS PETRIE, *appointed for the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.* (*Drawn up by the Secretary.*)

THE Committee issue the third list of photographs registered with them.

They have to report that all the photographs in their possession have been mounted, the balance in hand having been expended on this object.

The system of numbering and arrangement was published in the York (1906) report of the Committee. The following is a list of the numbers already allocated :—

1–2000.	The Royal Anthropological Institute, 3 Hanover Square, W.
2001–3000.	Professor J. L. Myres, The University, Liverpool.
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, Galewood Tower, Great Shelford, Cambridge.
6001–7000.	Professor J. L. Myres, The University, Liverpool.
7001–8000.	Mr. Edgar Thurston, Government Museum, Madras.
8001–9000.	Will be used for small series or single photographs.
(8002–8015.	Miss E. M. Hartland, Highgarth, Gloucester.)
9001–10000.	Dr. W. H. R. Rivers, F.R.S., St. John's College, Cambridge.
10001–11000.	Dr. C. G. Seligmann, 15 York Terrace, N.W.
11001–12000.	Dr. G. A. Auden and Dr. H. A. Auden, Education Office, Birmingham.
12001–13000.	Dr. A. C. Haddon, F.R.S., Inisfail, Hills Road, Cambridge.
13001–14000.	Not yet allocated.
14001–15000.	Dr. J. J. Lister, F.R.S., St. John's College, Cambridge.

The Committee ask to be reappointed, with a grant of 5*l.*

THIRD LIST OF PHOTOGRAPHS.

EUROPE.

ENGLAND.—*Photographed by* Dr. G. A. AUDEN, 54 *Bootham, York.*

Yorkshire.

11093. Bronze brooch with representation of lion, and two bone buckles (York Museum).
11094. Staghorn amulets (York Museum).
11095. Bone comb with Runic inscription (York Museum).
11096. Staghorn amulets with zoomorphic design (York Museum).
11097. Silver brooch with zoomorphic design (York Museum).
11098 Cross and human face (bone) (York Museum).

ASIA.

BORNEO: SARAWAK.—*Photographed by* Dr. A. C. HADDON, F.R.S., *Inisfail, Hills Road, Cambridge.* [Application for photographs should be made direct to Dr. Haddon. Cf. 'Head-Hunters, Black, White, and Brown.'] $4\frac{1}{4} \times 3\frac{1}{4}$.

12701. Drying upoh on darts.
12702. Ratan raft, Marudi.
12703. Preparing for a voyage, canoe with carved figure-head, Marudi.
12704. Two figure-heads of canoes.
12705. Sea Dayak (or Iban).
12706. Up-river scenery.
12707. Going up rapids, Madalam River.
12708. Girl offering borak to a 'boy' at Long Puah.
12709. Long Puah, Jangang's house.
12710. Long Puah, Jangang's house.
12711. Woman winnowing rice on a verandah (cf. 12838).
12712. Hose taking tribute in Fort, Marudi.
12713. Hose taking tribute in Fort, Marudi.
12714. Ratans in front of bazaar, Marudi.
12715. Kara jankeit, Ficus.
12716. Going up rapids, Madalam River.
12717 Malinau River, near source.
12718. Mulu bone cave.
12719. Mulu bone cave.
12720. Temporary skull-house, Long Puah.
12721. Temporary skull-house, Long Puah.
12722. House in construction on Tutau River, Batu Blah.
12723. Gourds containing skulls (Limbang).
12724. Brunei.
12725. Brunei.
12726. Brunei.
12727. Brunei, marketing.
12728. Brunei.
12729. Brunei.
12730. Brunei.
12731. Brunei.
12732. Brunei, fish traps.
12733. Brooketown.
12734. Brooketown, middle of village, man making string.
12735. Sibu, Malay-town.
12736. Mohammedan saint's grave, Baram Mouth.
12737. Sago factory (Limbang), rasping trunk of palm.
12738. Sago factory, man treading sago.
12739. Sago factory.

12740. Sago factory.
12741. Sago factory, man treading sago.
12742. Sago factory.
12743. Sago factory, rasping trunk of palm (larger scale).
12744. Sago factory.
12745. Fishing with jalai net, Tutau or Malinau River. Fish caught.
12746. Fishing with jalai net, Tutau or Malinau River. Fish caught.
12747. Fishing with jalai net, Tutau or Malinau River.
12748. Wooden protecting figure at Long Sulan (Long Pokun people).
12749. Up-river scenery, Dapoi River.
12750. Decorated Pontianak Malay hat.
12751. Rice granary in padi field.
12752. Rice granary in padi field.
12753. Tinjar River, tree arch.
12754. Poling up rapids, Dapoi River.
12755. Poling up rapids, Dapoi River.
12756. Images outside Long Sulan.
12757. Long Sulan, sacred stones and images of tigers.
12758. Drift wood at mouth of Baram River.
12759. Mohammedan saint's grave, mouth of Baram River.
12760. Mohammedan saint's grave, mouth of Baram River.
12761. Verandah of Hose's house.
12762. A midday meal, making the fire.
12763. Buffaloes in jungle, Baram River.
12764. Nest of maias (orang-utan).
12765. Poles at encampment, Marudi.
12766. Boat race, Marudi.
12767. Temporary sleeping-hut, Baram River.
12768. A.C.H. in canoe, Pata River.
12769. Natives in canoe, Pata River.
12770. Clearing for padi, Tinjar River.
12771. Group of natives.
12772. Tree burial, Malinau River.
12773. Long Tisam, Tinjar River.
12774. Long Sulan ceremonial poles.
12775. Taking tribute, Long Dapoi.
12776. Boat race, Marudi.
12777. Boat race, Marudi.
12778. Boat race, Marudi.
12779. Boat race, Marudi.
12780. Boat race, Marudi.
12781. Eggs in cleft sticks as an offering.
12782. Tuba-fishing. Men with war coats.
12783. Tuba-fishing.
12784. Tuba-fishing.
12785. Decorated baskets, Sarebas Dayak.
12786. Mausoleum, Baram District.
12787. Roof with carved beam, Aban Abit's house, Long Tisam.
12788. Painted partition, Long Tisam.
12789. Painted wall of house with two hats, Long Tisam.
12790. New Fort opposite Tama Bulan's house.
12791. Sea Dayak (Iban) cotton blanket, puah.
12792. Sea Dayak (Iban) cotton blanket, puah.
12793. Kenyah woman's hat (Tama Bulan's daughter).
12794. Ceremonial posts and stones in front of Tama Bulan's house.
12795. Fisherman's hut, Brooketown.
12796. Batu Blah Village, Tutau River.
12797. Side view of a long house, Tutau River.
12798. Long house (? Orang Bukit), (Kadayan), Long Lenai, Tutau.
12799. Fish trap, Brooketown.
12800. Winnowing rice, Brooketown.
12801. Ceremony of skull-moving, Long Puah, Lobong River.
12802. Grave on Rejang River, near Sibu.

12803. Fastening basket of skulls in new house, Long Puah, Lobong River.
12804. Verandah, Long Puah, McD. measuring.
12805. Long houses (? Aban Abit's houses), Long Tisam, Tinjar.
12806. Long house.
12807. Bazaar, Marudi.
12808. Residency, Limbang.
12809. Residency, Limbang.
12810. Camp on Mount Dulit, 4,000 ft.
12811. Foliage, Mount Dulit, 4,000 ft.
12812. Trophy of Murut skulls.
12813. Mount Dulit.
12814. Skull trophy.
12815. Lobong River, buttress tree and canoe.
12816. Two Malangs.
12817. Leaf beds in bank of Malinau River.
12818. Scott-Keltie Falls, Mount Dulit.
12819. Up-river scenery.
12820. Tukanaiah (servant), Limbang.
12821. Skulls in verandah, Long Tisam.
12822. Skulls in verandah, Long Tisam.
12823. Skulls in verandah, Long Tisam.
12824. Verandah of a long house.
12825. Up-river scenery, overhanging tree, man on krangang.
12826. Ray's Rapid, Dapoi River.
12827. Sea Dayak (Iban) petticoat, bidang.
12828. Two Sea Dayak fortmen (side), Kidara (tall) and Manchu (short).
12829. Two Sea Dayak fortmen (front), Kidara and Manchu.
12830. Tatued man, Jalai, a Rejang Sea Dayak.
12831. Tatued man, Ajong, from Bakong.
12832. Two Sea Dayak fortmen, Biji (short) and Sui (tall).
12833. Kenyah man on krangang.
12834. Man cutting log.
12835. Two boys (one with carrying-basket).
12836. Two Madangs, Tama Ipoi Bilong and man.
12837. Lelak man.
12838. Woman winnowing rice in verandah (cf. 12711) (best).
12839. Sea Dayak, Chrang from Batang Lupar.
12840. Sea Dayak and wife, Chrang and Lada.
12841. Two Kenyah women (two types).
12842. Kenyah woman, Bulan.
12843. Two Kenyah women (narrow and broad faced types).
12844. Two Kenyah women.
12845. Two Punans, Long Puah.
12846. View from Limbang towards Brunei.
12847. View from Limbang, towards Brunei.
12848. Group of Sea Dayak women at Sibu, Rejang. Fat girl with corslet is a Kayan.
12849. Lad with brass-studded band in mouth in front of toothless gums (? Iban).
12850. Sea Dayak (Chrang, Batang Lupar) and wife (Lada), Limbang.
12851. Man (? tribe).
12852. Figure-head of canoe.
12853. Figure-head of canoe.
12854. Figure-head of canoe.
12855. Figure-head of canoe, Long Kiput.
12856. Old Kenyah man.
12857. Three lads, Marudi.
12858. Fort, Marudi.
12859. Judging rice, Marudi.
12860. Bazaar, Marudi.
12861. Bazaar, Marudi.
12862. Bazaar, Marudi.
12863. Lad, Marudi.
12864. Sea Dayak dancing, Marudi.

12865. Sea Dayak dancing, Marudi.
12866. Iban mural painting.
12867. Model of Hornbill for festival, Marudi.
12868. Model of Hornbill for festival, Marudi.
12869. Sea Dayak dancing.
12870. Floating houses (Malay), Marudi.
12871. Two Sea Dayaks (front), Marudi.
12872. Four bezoar stones.
12873. Two Sea Dayaks (side), Marudi.
12874. Boats on Tutau River.
12875. Sea Dayak (Iban) petticoat, bidang, gold embroidery on green.
12876. Hill's Range.
12877. Mount Dulit.
12878. Old Kenyah man.
12879. Kenyah man.
12880. Mount Dulit.
12881. Kenyah man.
12882. Man (side) with distended lobe of ear.
12883. Embroidered chawat, Iban.
12884. Embroidered sash, Iban.
12885. Kanowit decorated baskets.
12886. Beaded baskets.
12887. Sea Dayak (Iban) petticoat, bidang.
12888. Three boys (up-country).
12889. Man with curly hair (? Kenyah), cf. 12900.
12890. Two hooks, Baram.
12891. Two men (cf. 12943), Punans, Bok River.
12892. Sea Dayak (Iban) embroidery.
12893. Hill's Range.
12894. Mount Dulit.
12895. Two boys.
12896. Stone implements.
12897. Stone implements.
12898. Sea Dayak (Iban) embroidery.
12899. Stone hook.
12900. Man with curly hair (cf. 12889).
12901. Two bezoar stones.
12902. Stone implement in Sarawak Museum.
12903. Stone implement in Sarawak Museum.
12904. Decorated hat, Malanau (Milano).
12905. Decorated hat, Madang.
12906. River scene.
12907. Waterfall, Pata.
12908. Pattern on bamboo receptacle, Kayan.
12909. Unshipping at rapids, Madalam River.
12910. Baram River at Marudi.
12911. Kenyah man (full).
12912. Kenyah man ($\frac{3}{4}$ view).
12913. Kenyah man (side) (cf. 12917)
12914. Kenyah man (front).
12915. Berantu (wooden image).
12916. Man.
12917. Man (cf. 12913).
12918. Rice-houses on river-bank.
12919. Back view of a Sea Dayak with seat-mat (cf. 12925).
12920. Seat-mats.
12921. Sukun beside the hornbill (cf. 12926, 12867).
12922. Patterns on tatu blocks, Murut and Kayan.
12923. Painted shield, Long Pokun, Kenyah.
12924. Foliage.
12925. Cf. 12919, Sea Dayak wearing a seat-mat.
12926. Iban mural painting.
12927. Kenyah man (cf. 12934).

12928. Kenyah man.
12929. Iban boy with ringworm (front).
12930. Iban boy with ringworm (back).
12931. Man (hair).
12932. Baram River from Marudi.
12933. Carved Iban shuttle.
12934. Details of carved Iban shuttle (other side).
12935. Details of carved Iban shuttle (other side).
12936. Areca palms, Marudi.
12937. Rubbing of Kenyah pattern.
12938. Rubbing of Kenyah pattern.
12939. Rubbing of Kenyah pattern (dog).
12940. Rubbing of Kayan pattern (dog).
12941. Rubbing of Kalabit pattern.
12942. Two Punan men.
12943. Cf. 12891.
12944. Rubbing of Iban thread-case.
12945. Chinese traders, Marudi.
12946. Sea Dayak family bathing.
12947. Ceremony before skull-house.
12948. Pulling up skull basket.
12949. Source of Malinau River.
12950. Boat race, Kuching.
12951. Boat race, Kuching.
12952. Boat race, Kuching.
12953. Boat race, Kuching.
12954. Boat race, Kuching.
12955. Boat race, Kuching.
12956. Boat race, Kuching.
12957. Boat race, Kuching.
12958. Boat race, Kuching.
12959. Boat race, Kuching.
12960. Kuching, sunset.

(Numerous negatives of decorative art are also available.)

OCEANIA.

NEW GUINEA.—*Photographed by* A. WILKIN and A. C. HADDON, *Inisfail, Hills Road, Cambridge.* [Application for photographs should be made direct to Dr. Haddon. Cf. 'Reports Camb. Exped. to Torres Straits' and 'Head Hunters, Black, White, and Brown.'] $4\frac{1}{4} \times 3\frac{1}{4}$.

12001. Hula man, (A) profile (Tinea).
12002. C.G.S. at work (Hula).
12003. Hula child (oblique eyes), full face.
12004. Same as 12001, full face.
12005. Bleeding with miniature bow and arrow (Hula).
12006. Hula native, profile (Tinea), hair in cloth.
12007. Same as 12005.
12008. Hula man with tinea.
12009. Hood Peninsula, driving in bush.
12010. Gaile, near view of houses in sea.
12011. Kalo.
12012. Gaile (distance).
12013. Drawings of Kerepunu belts.
12014. Gaile and natives, group on shore.
12015. Kamali, Dubu.
12016. Gaile, near view of houses in the sea.
12017. Gaile natives.
12018. Kamali, Dubu and Chief's house.
12019. Old woman washing a pot in the creek, Kalo.

12020. Kalo, drying grass.
12021. Street, Delena (pots and hunting for lice).
12022. Delena.
12023. In the bush near Hula.
12024. Steeple house, Kalo.
12025. Delena, house, and woman making pottery.
12026. Delena, canoe and mangroves.
12027. Murray Island.
12028. Delena (pottery making).
12029. Delena (child in bag).
12030. Two Wara (Pokau) natives (man and wife).
12031. Houses, Delena.
12032. Same as 12028.
12033. Ceremony at Babaka (nude girls on platform).
12034. Ceremony at Babaka (clothed girls on platform).
12035. Kerepunu, man hollowing bowl.
12036. Kerepunu, man hollowing bowl.
12037. Kerepunu, canoe-making (general view).
12038. Alukune, fishing village close to Kerepunu.
12039. Kerepunu natives seeing off a prisoner.
12040. Part of the marine village of Hula.
12041. Kerepunu, two men hollowing a canoe.
12042. Kerepunu, hollowing a canoe.
12043. Dance at Babaka.
12044. Firing outside of canoe, Kerepunu.
12045. Group of dancers, Babaka (♂ and ♀).
12046. Group of dancers, Babaka (♂ and ♀).
12047. Dance at Babaka.
12048. Canoe-making, Kerepunu (back view of three ♂).
12049. Dance at Babaka.
12050. Dance at Babaka.
12051. Firing inside of canoe, Kerepunu.
12052. Male dancers, Babaka, with mouth charm.
12053. Men hollowing out a canoe, Kerepunu (three ♂, front view).
12054. Dance at Babaka.
12055. Hula women.
12056. Boys' game, Hula, Kinimali.
12057. Boys' game, Hula, Korikini, hair.
12058. Boys' game, Hula, Korikini.
12059. Boys' game, Hula, Toitoi.
12060. Boys' game, Hula, Korikini, fingers.
12061. Boys' game, Hula, Korikini, ears.
12062. Boys' game, Hula, Korikini, ears.
12063. Boys' game, Hula, Korikini, ears.
12064. Boys' game, Hula, Rapurapu.
12065. Palm-leaf toys, Hula.
12066. Woman making fire (groove method), Hula.
12067. Church at Saibai.
12068. House at Saibai.
12069. Swamp at Saibai.
12070. Saibai, pile dwellings.
12071. Saibai, pile dwellings.
12072. Saibai, pile dwellings.
12073. Tud, huts on ground.
12074. Tud, huts on ground.
12075. Saibai, Church (exterior).
12076. Rev. J. Chalmers and Chief of Saibai.
12077. Tud, coral image in bush.
12078. Saibai (two ♂).
12079. 'May Meeting' at Mabuiag, present of food.
12080. Canoe at Mabuiag.
12081. Bow of canoe at Mabuiag.
12082. Stern of canoe at Mabuiag.

12083-90. *Pathological.*
12091. House on fire at Mabuiag.
12092. Cleaning pearl-shell at Mabuiag.
12093. House on fire at Mabuiag.
12094. Dugong, Mabuiag.
12095. Restoration of totem shrines, Yam.
12096. Snake and Dugong scarifications on two women.
12097. Myrmecodium, Mabuiag.
12098. Model of canoe, Mabuiag.
12099. Model of canoe, Mabuiag.
12100. Model of canoe, Mabuiag.
12101. Cuscus, Mabuiag.
12102. Myrmecodium, Mabuiag.
12103. Snake totem scarification, Mabuiag.
12104. Making a scar, Mabuiag.
12105. Snake totem scarification, Mabuiag.
12106. Cuscus, eating.
12107. Two old women, Mabuiag midwives.
12108. Two old women, Mabuiag midwives.
12109. Kwoiam's victims at Pulu, row of stones.
12110. Head-post, &c., Pulu.
12111. Part of Kwod, Pulu.
12112. Cove of Mumugubut at Pulu.
12113. Rocks at Pulu.
12114. Kwod, Pulu (positions of the clans).
12115. Cave (Augudalkula), Pulu.
12116. Rock-painting, Pulu, waterspout.
12117. Hand-marks on rock which fell from the sky, Pulu.
12118. Augudalkula.
12119. Rock-painting, Pulu, man beating drum, and dancers
12120. Augudalkula, Pulu.
12121. Taburi, house where we slept.
12122. View from Taburi.
12123. House at Taburi, showing side verandah.
12124. Two mountaineers (side), Ari and Yube of Wamai.
12125. A 'Bushman' at Rigo.
12126. Women carrying grass for thatch at Rigo.
12127. Front face, young Motu ♂.
12128. Side face, young Motu ♂.
12129. Two mountaineers (side), Hogeri (with crescent).
12130. Two mountaineers (front).
12131. Mountain girl.
12132. Same as 12124 (full face), Wamai.
12133. Motu charms.
12134. Same as 12125 (full length).
12135. Rigo village.
12136. Chief of Taburi whittling spears with a boar's tusk
12137. Dance at Hula.
12138. Dance at Hula.
12139. Dance at Hula.
12140. Carving dubu-post, Rigo.
12141. Charms, Port Moresby.
12142. Charms, Port Moresby.
12143. Charms, Port Moresby.
12144. Mountaineer, Goria of Wamai.
12145. Chief of Agi (with hat).
12146. Chief of Agi (without hat, side).
12147. Same as 12144 (side).
12148. Same as 12146 (front).
12149. View of bush near Taburi.
12150. Same as 12146.
12151. Our hosts at Taburi (full length).
12152. Our hosts at Taburi (side, upper part).

12153. Women at Taburi.
12154. Village of Taburi.
12155. House at Ziria, Yule Island.
12156. Lads at Ziria.
12157. Lad, side face, at Ziria.
12158. House at Ziria.
12159. Marea at Ziria.
12160. Lads at Ziria.
12161. Street, Ziria.
12162. Street, Ziria, with dogs.
12163. House, Ziria.
12164. Decorated board in front of a marea.
12165. Houses at Ziria.
12166. Dabbing a pot with a decoction of mangrove bark.
12167. 'Turtle-cutting,' Port Moresby.
12168. Three natives of Port Moresby (Koitapu, side).
12169. Cleaning pots, Port Moresby.
12170. Turtle-cutting, Port Moresby.
12171. Animal masks from Gulf.
12172. Firing pots, Port Moresby.
12173. Same as 12168 (front).
12174. Same as 12173.
12175. Three masks and bull-roarer from Gulf.
12176. Taking pots off fire, Port Moresby.
12177. Carrying turtle (before cutting).
12178. House at Mohu (hammock).
12179. Mohu.
12180. House at Mohu.
12181. Houses at Mohu (gable end).
12182. Mohu.
12183. Mohu, street.
12184. Decorated gable-beam, Mohu.
12185. House at Mohu with tablet.
12186. Marea at Mohu (side).
12187. Houses at Mohu.
12188. Mohu.
12189. Great marea at Mohu (front).
12190. Pottery making, Port Moresby, moulding bowl.
12191. Pottery making, Port Moresby, moulding bowl.
12192. Beating pots.
12193. Scraping inside of pot.
12194. Shaping edge of pot.
12195. Shaping edge of pot.
12196. Marking edge of pot.
12197. Sprinkling water on clay.
12198. Marking rim of pot with trade-mark.
12199. Same as 12197.
12200. Same as 12197.
12201. Two unfinished pots.
12202. Clay for making pots.
12203. Removing pots off the fire.
12204. Pots drying.
12205. Potters in house.
12206. The feast. Unfinished pot.
12207. The feast. Unfinished pot.
12208. Same as 12206. Firing pots.
12209. Firing pots.
12210. Mer, feast.
12211. Mer, feast.
12212. Mer, feast.
12213. Mer, feast.
12214. Kneading clay for pots, Port Moresby.
12215. Cylinder, half finished.

12216. A 'spell,' woman smoking.
12217. Three stages of pot-making.
12218. Everting rim of pots.
12219. Half-finished pot.
12220. Shaping edge.
12221. Three states of pots, mixing and kneading clay.
12222. Children playing at Hanuabada, walking on heads.
12223. Hanuabada, Port Moresby.
12224. Creek on road to Tuburi.
12225. Pots and firewood ready for firing.
12226. Firing a single pot.
12227. Brushing a pot with decoction of mangrove bark.
12228. Preparing for feast, Mer.
12229. Pulling horse out of salt-pan.
12230. Tug of war.
12231. Kaketut, Mer.
12232. 'Cat's Cradle,' Port Moresby.
12233. Frog game.
12234. Mountaineer's foot.
12235. Mountaineer's foot.
12236. Hula man, side face, A (cf. 12246).
12237. Mountaineer, Babu of Ubere.
12238. Mountaineer, Babu of Ubere (side).
12239. Two mountaineers (side).
12240. Mountaineer, Ruiva of Umuna.
12241. Mountaineer, Ruiva of Umuna (side).
12242. Mountaineer, Amiro of Wamai.
12243. Mountaineer, Amiro of Wamai (side).
12244. Hula man, mop of hair.
12245. Hula man (side).
12246. Hula man, shell in hair.
12247. Clay for pots, Port Moresby.
12248. Beating a pot.
12249. Moulding a pot.
12250. Ready to fire pots.
12551. Cf. 12249.
12252. Cf. 12247.
12253. Death dance (markai) at Mabuiag.
12254. Death dancers, Mabuiag.
12255. Death dancers, Mabuiag.
12256. Death dancers, Mabuiag.
12257. Death dancers, Mabuiag.
12258 Death dance at Mabuiag (four men front).
12259. Death dancers, four (three men side).
12260. Death dancing at Mabuiag (one man front).
12261. Death dancing at Mabuiag (one man front)
12262. Death dancing at Mabuiag (one man side).
12263. On Tong, Javanese 'boy.'
12264. Gawer stone (cf. 12374).
12265. House at Mer.
12266. Canoe at Mer.
12267. Canoe at Mer.
12268. Gawer stone (cf. 12264).
12269. Interior of 'humpy,' Mer.
12270. Canoe with masts.
12271. Decoration on top of 12265.
12272. Cf. 12269.
12273. A Murray Islander.
12274. Cf. 12270.
12275. Houses at Mer (Cæsar's).
12276. Canoe, end-on, Mer.
12277. Mabuiag—Wiwai at Gomu.
12278. Kwoiam's house, Mabuiag.

12279. Man imitating death of Kwoiam.
12280. Landing turtle.
12281. Kwoiam's grave, Mabuiag.
12282. Turtle-cutting, Mabuiag.
12283. View from Kwoiam's look-out.
12284. Cf. 12281.
12285. Cf. 12282.
12286. Cf. 12282.
12287. Tom after turtle-cutting, Mabuiag.
12288. Old Moatta.
12289. Old Moatta shelters.
12290. Old Moatta shelters.
12291. Mabuiag village street.
12292. Cf. 12290.
12293. Moatta men (profile).
12294. Moatta men (full face).
12295. Cf. 12292.
12296. Two Moatta women.
12297. Daru.
12298. Old Moatta.
12299. European's house on Daru.
12300. Three Australians, Mabuiag (profile).
12301. Mer, man (profile); cf. 12307.
12302. Australians (full face).
12303. Australians (profile).
12304. Cf. 12300 (full face).
12305. Mesaticephalic Australian.
12306. Australians (profile).
12307. Cf. 12301 (full).
12308. Australians (profile).
12309. Australians (group).
12310. Interior of Long House, Kiwai.
12311. Woman and child, Kiwai.
12312. General view, Iasa, Kiwai.
12313. Sop-sop bananas, Murray.
12314. Long House, Kiwai.
12315. Sus Papuensis, Kiwai.
12316. Children, Kiwai.
12317. Cf. 12311.
12318. Darnley Island.
12319. Kiwai, beach.
12320. Women of Kiwai.
12321. Sop-sop bananas (large scale).
12322. Woman (leucoderma), Murray.
12323. Archers, Murray.
12324. Round House, Murray.
12325. Singing at Las (Malu).
12326. Tapau.
12327. Charlie.
12328. Dela and Ben.
12329. Landing at Murray.
12330. Three Zogo men (Malu), Las.
12331. Malu ceremony at Gazir.
12332. Malu circular dance, Las.
12333. Malu pigeon men, Las.
12334. Malu pigeon and dog men, Las.
12335. Malu dog men.
12336. Malu (phonograph).
12337. Malu drum and clubs.
12338. Group at Las.
12339. Mer from Gelam, fringing reef.
12340. Shrine of Zabaker, Mer.
12341. Shrine of Zabaker, Mer.

12342. Ceremonial stones at Dam.
12343. Ceremonial stones at Dam.
12344. Wag or Wind Zogo.
12345. The Iruam stone on reef, Mer.
12346. Cf. 12344.
12347. Fish weirs.
12348. Las, showing palisades.
12349. Village of Las.
12350. Village of Las.
12351. Gorge at Mer, with reef.
12352. View from verandah of mission house, Mer.
12353. The Barat stone with shell on top.
12354. Wanu (full face).
12355. Papi and Doboro (full face).
12356. Davita and Wag (full).
12357. Davita and Wag (profile).
12358. Wanai, &c.
12359. Boa and family.
12360. Ziai neur at Damud, Danar.
12361. Waier.
12362. Au Kosker, Waier.
12363. Geigi's spear, Waier.
12364. Tree at Waier.
12365. Man and 2 women (side).
12366. Waipem, a turtle shrine, Waier.
12367. B. Gasu and J. Rice, jun. (profile).
12368. Dauar and Waier, and Sorkar, a fish shrine.
12369. Cf. 12367 (full).
12370. Dauar coconut Zogo.
12371. U Zogo, Dauar.
12372. Present of food.
12373. Present of food.
12374. Gawer's shrine on Dauar.
12375. Gawer's shrine on Dauar (large scale).
12376. Marriage in church, Murray.
12377. Marriage in church, Murray.
12378. Dauar—canoe of Abob.
12379. Sacred ground, Waier.
12380. Turtle tracks, Dauar.
12381. Ziai neur on Dauar (two stone figures).
12382. Waier.
12383. Group at Dauar.
12384. The Meidu stone at Dauar.
12385. Cf. 12381.
12386. Andersen.
12387. Gizu and rain charm, Murray.
12388. Fish weirs on reef, Murray.
12389. Cf. 12387.
12390. Cf. 12387.
12391. Queen's birthday, children on Mer.
12392. Stratified volcanic ash, Darnley.
12393. Stratified volcanic ash, Darnley.
12394. Cf. 12387.
12395. Profile of 12402.
12396. Smoke (full).
12397. Smoke (profile).
12398. Biro (profile).
12399. Biro (full).
12400. Dean (full).
12401. Sambo.
12402. Cf. 12395 (full).
12403. Cf. 12401 (side)
12404. Beni (full)

12405. Cf. 12400 ♀ (side).
12406. Beni (side).
12407. The Bishop's house, Yule Island.
12408. Two Koiari men of Makabiri (front).
12409. Two Koiari men of Makabiri (side).
12410. Two Koiari men of Makabiri (front).
12411. Two Koiari men of Makabiri (side).
12412. Two Koiari men of Ienari and Agobiri.
12413. Two Koiari men of Ienari (side).
12414. At Ziria.
12415. R.C. Mission, Yule Island.
12416. Boys' games at Veifa, dressed in leaves.
12417. Restoration of Bomai ceremony, Mer.
12418. Port Moresby at dawn.
12419. Cf. 12414, catching lice.
12420. 'Chief's house,' Mawi.
12421. Boy fishing with bow and arrow, Port Moresby.
12422. Firing pots, Port Moresby.
12423. Queen's Birthday, Murray. Men dancing.
12424. Queen's Birthday, Murray. Men dancing.
12425. Queen's Birthday, Murray. Men dancing.
12426. Queen's Birthday, Murray. Men dancing.
12427. Queen's Birthday, Murray. Men dancing.
12428. Queen's Birthday, Murray. Men dancing.
12429. Queen's Birthday, Murray. Men dancing.
12430. Queen's Birthday, Murray. Children dressed up.
12431. Queen's Birthday, Murray. Pager.
12432. Queen's Birthday, Murray. Zera markai.
12433. Queen's Birthday, Murray. Group.
12434. Queen's Birthday, Murray. Dancers.
12435. Trophy of skulls.
12436. Ceremony, Murray. Zera markai.
12437. Spectators' beating drums, Murray.
12438. Children on grass, Murray.
12439. Dugong charm and harpoon points, Mer.
12440. String-making, Port Moresby.
12441. Tatana, Port Moresby.
12442. Houses at Tatana.
12443. Babaka.
12444. Babaka, a house.
12445. Carrying fruit, ditto.
12446. Nest of ti bird.
12447. Cf. 12444.
12448. Coronation Day, Port Moresby. Gun-boats saluting
12449. Decorated human jaw.
12450. Shell with stones from Enau Zogo (cf. 12474).
12451. Tatana, children dancing.
12452. Pot-makers, Port Moresby.
12453. String-making, Port Moresby.
12454. String and bag making, Port Moresby.
12455. Top-spinning, Murray.
12456. Geigi and Iruam Muris top.
12457. Kaikai in Murray.
12458. Copper Maori opened.
12459. Copper Maori opening.
12460. Round House, Darnley.
12461. Street in Thursday Island.
12462. Koko's lugger, Darnley.
12463. Ager, an Aroid.
12464. Thursday Island.
12465. Cf. 12458.
12466. After church, Darnley.
12467. Cf. 12457.

12468. Darnley.
12469. Darnley.
12470. Houses, Darnley.
12471. Tomog Zogo, Murray.
12472. Tomog Zogo, Murray.
12473. Girls playing in sea.
12474. Enau Zogo, Dauar.
12475. Zogo (?).
12476. Ai geres Zogo in garden.
12477. Ai geres Zogo in garden.
12478. Girls playing on beach (cf 12603).
12479. Models of bud lu, Mer.
12480. Tomog Zogo.
12481. View on a Road, Murray
12482. Markep stone on Dauar.
12483. Finau and family.
12484. Finau and family.
12485. Irado and her basket, stones in Mer.
12486. Minicoi.
12487. Carts at Surabaija.
12488. Port Said.
12489. Minicoi.
12490. Surabaija.
12491. A Kampong in Java.
12492. Duke of Westminster, Goode Island.
12493. Boats at Surabaija.
12494. Boats at Surabaija.
12495. Alkantara, Suez Canal.
12496. Minicoi.
12497. Divers at Aden.
12498. Feluccas, Suez Canal.
12499. Cf. 12491.
12500. Man at Mohu (side).
12501. Men at Ziria (front).
12502. Men at Ziria.
12503. Drying fish, Mohu.
12504. Catching lice, Ziria.
12505. Men at Ziria (full).
12506. Men at Ziria (side view).
12507. Pinupaka.
12508. Mask from Waima.
12509. Mask from Waima.
12510. Model of Waiet, Dauar.
12511. Interior of big marea.
12512. Boy at Mohu.
12513. Dandy at Mohu.
12514. Girls at Mohu.
12515. Tumble-down marea.
12516. Davita (profile).
12517. Work (side).
12518. Cf. 12516 (full).
12519. Bugi man and a boy.
12520. Imagi (side).
12521. Komaberi (full).
12522. Komaberi (side).
12523. Cf. 12519 (side).
12524. Imagi (full).
12525. Ulai (side).
12526. Alo (full).
12527. Boy (pathological).
12528. Dead infant.
12529. William and James (full)
12530. Giaz (side).

12531. Giaz (full).
12532. Kilarup (side).
12533. Kilarup (full).
12534. Poi (full).
12535. Poi (profile).
12536. Pasi (profile).
12537. Pasi (full).
12538. Gadodo (full).
12539. Gadodo (profile).
12540. Cf. 12529 (side).
12541. Alo (side).
12542. Hula, present to Mr. English.
12543. Hula, tatuing, three girls.
12544. Hula, phonog. (cf. 12624).
12545. Cf. 12548, tatuing.
12546. Hula, game, revolving.
12547. Hula, leap-frog.
12548. Cf. 12545, painting.
12549. Hula, tatuing, painting.
12550. Babaka, ceremony (nude, large).
12551. On way from Babaka.
12552. Sinaugolo boy.
12553. Woman of Hula.
12554. Back view of a tatuëd woman.
12555. Hula, balancing game.
12556. Hula, marine village.
12557. Dancer, Hula.
12558. Dance, Hula.
12559. Dance, Hula.
12560. In Hula.
12561. Hula.
12562. Raising a pile, Hula.
12563. Raising a pile, Hula.
12564. Raising a pile, Hula.
12565. Dance, Hula.
12566. Children playing in sand, Hula.
12567. Isau mani, Mer.
12568. Gulf shields and bullroarer.
12569. Lakatoi model.
12570. Making arm shell, Port Moresby.
12571. Making arm shell, Port Moresby.
12572. Ad giz, Mer.
12573. Profile, Motu lad, Port Moresby.
12574. Hogeri man (front).
12575. Hogeri man (side).
12576. Cf. 12573 (full).
12577. Girls at Port Moresby.
12578. Ikoro village near Vatorata.
12579. Houses near Vatorata.
12580. Yam charms, &c.
12581. Cf. 12577.
12582. Dogai mask, Mer.
12583. Tree-house, Gasiri.
12584. Tree-house building, Gasiri.
12585. Tree-house, Gasiri.
12586. Tree-house, Gasiri.
12587. Group at Kapa Kapa.
12588. Uafak, marine village.
12589. Widow.
12590. Fishing in creek, Kapa Kapa.
12591. Burnt pile village, Kapa Kapa.
12592. Fishing in Kapa Kapa.
12593. Scenery in Bush near Banale.

12594. Group of party at Mabuiag.
12595. Group of party at Mabuiag.
12596. Bush scene, Mabuiag.
12597. Bush scene, Mabuiag.
12598. Bush scene, with termite hill, Mabuiag.
12599. Gun and copper ingot, Mabuiag.
12600. Myrmecodium, Mabuiag.
12601. Terrier and cuscus.
12602. Terrier and cuscus.
12603. Girls' game on sand (cf. 12473, 12478).
12604. Chief of Ziria (Yule Island).
12605. Rocks in Yam.
12606. Ubaro Zogo in Yam.
12607. Augudau kupai in Yam.
12608. Pictograph, Hammond I.
12609. Pictograph, Hammond I.
12610. Ulai (front).
12611. Albino and ordinary boy, Hula.
12612. Dubu, Kapa Kapa.
12613. Cf. 12570.
12614. Kwoiam's water-holes, Mabuaig.
12615. Work (full face).
12616. Acuity of vision (with W. H. R. R.), Mabuiag.
12617. Acuity of vision, Mabuiag.
12618. Colour-wheel.
12619. Colour-wheel (out of doors).
12620. Group of our helpers, Mabuiag.
12621. Gizu.
12622. Waria.
12623. Tom.
12624. Hula, phonograph (cf. 12544).
12625. Hula, singing into phonograph.

(A large number of negatives of decorative art, and magical and other objects, are available.)

POLYNESIA.—*Photographed by* Dr. J. J. LISTER, F.R.S., *St. John's College, Cambridge.*

Tonga.

14001. Tevita, a Tongan man.
14002. Isaaki Futu, a chief man at Vavau.
14003. The Buli (Mayor) of Mua, Tongatabu.
14004. Vaca Futu, a Tongan Matabele.
14005. Tongan man, wearing a sisi from Eua. (The ferns used in making it are peculiar, in the Tongan Group, to the volcanic tracts on Eua.)
14006. The Feifikau (preacher) and his family, Mua, Tongatabu.
14007–14025. Tongan men.
14026. Sons of Junia, a chief man of Tongatabu.
14027. Tongan boys.
14028. Tongan baby boy.
14029, 14930. Tongan boy.
14031. Man and women of the Chief Tugi's household, Mua, Tongatabu.
14032. A chief woman at Mua.
14033. Chief women at Mua.
14034. Woman of Hafa'i, wearing an Eua sisi.
14035. Woman with her hair dressed with lime.
14036. Chief woman at Vavau.
14037. Woman and child.
14038. Woman and boy with shaved head.
14039–14052. Women.
14053. Two girls at Tongatabu. Upper is Fijian type; other, Tongan type.
14054. 'College' girls, Nukualofa.
14055. Girl with boatswain-bird's feathers. Wearing mat for mourning.

14056. Girl (chief).
14057–14079. Girls.
14080. Children (daughters) of Junia, a Chief of Tongatabu.
14081. The colony of fruit-eating bats (Pterobus; native name, 'beka') at Hihifo, Tongatabu. They hang on Casuarina and fig-trees in the open space of the village of Hihifo, and while thus hanging are tabu. The Hihifo tapa bears a representation of them marked 'Roe tauga beka' (the crowd of bats).
14082. The Ha'amonga Maui, portal leading to a group of ancient burying-places near Niutoa, eastern end of Tongatabu.
14083. The Ha'amonga Maui, with man wearing half coconut leaf round waist.
14084. Corner-stone of one of the Tuitonga burying-places, Mua.
14085. Large slab of conglomerate shore rock—originally in one piece in the side of one of the Tuitonga burying-places, Mua.
14086. Corner of one of the Tuitonga burying-places, Mua.
14087. Corner of same burying-place. A volcanic stone, probably from volcanic island of Tofua, is used at the corner. The other stones are of the ordinary shore conglomerate.
14088. R.C. cemetery and ancient Tuitonga burying-place, Mua.
14089. Slab of shore rock at side of one of the Tuitonga burying-places, Mua.
14090. Modern cemetery, Nakualofa, Tongatabu.
14091. Woman anointing husband's grave; wearing mat of mourning.
14092. Tongans; woman wearing mat of mourning.
14093, 14094. Two Tongan and one Samoan girl catching limes.
14095. Tongan children's game.
14096. Girl playing nose flute.
14097. Girl playing nose flute.
14098. Gathering at Vavau.
14099. Paddle dance, Tongatabu.
14100–14102. Phases in the dance, Vavau.
14103. Laka-laka, Vavau.
14104. Women beating out the bark of the paper mulberry for tapa.
14105. Women adding the final marks to a sheet of tapa, Nukualofa.
14106. Woman wearing the Hihifo tapa.
14107. Women making sisis, Mua.
14108. Girls fishing with hand nets on reef opposite Nukualofa.
14109. A kava party (a sheet of tapa beyond).
14110. Men making kava; pounding instead of chewing now generally employed.

Niue.

14111, 14112. Men.

Hervey Group.

14113–14118. Men of Mangaia.

Fiji.

14119–14121. Men at Nagarawai, Viti Levu.
14122. Men and women at Nagarawai.
14123. Village in interior of Viti Levu.
14124. Interior of Fijian house, Naroko roko yama, Viti Levu.

Samoa.

14125. Anapo, a chief man at Safata, Upolu, and some of his household.
14126. Men, showing tatuing.
14127, 14128. Men.
14129, 14130. Fanlulia, wife of Siu-manu-tafa, Chief of Apia.
14131, 14132. Daughter of Siu-mana-tafa.
14133, 14134. Women, Tutuila.
14135–14137. Women.
14138. Group of men on south coast of Tutuila.
14139–14140. Men in canoe, Pango-pango Harbour, Tutuila.

14141. Dance by Anapo's house, Safata, Upolu.
14142. Safa, south coast of Upolu.

Union Islands.

14143, 14144. Man.
14145. Women.

AUSTRALIA.

QUEENSLAND.—*Photographed by* Dr. J. J. LISTER, F.R.S., *St. John's College, Cambridge.*

14146, 14147. Native man (full face and profile), photographed at Mount Hutton Station.

See also Nos. 12300–12309, p. 429.

The 'Metabolic Balance Sheet' of the Individual Tissues.—Final Report of the Committee, consisting of Professor GOTCH (*Chairman*), Mr. J. BARCROFT (*Secretary*), Professor E. H. STARLING, *and* Professor T. G. BRODIE.

THE Committee appointed in 1903 have since that time lost one of their members—Sir Michael Foster, K.C.B.—in whose place Professor Brodie was appointed in 1907.

The Committee had for their object the development of what seemed likely to be a fruitful field of physiological inquiry. It was recognised from the first that the experimental difficulties would be considerable, and it was therefore thought desirable to ensure the co-operation of a number of investigators who were especially well qualified for the study of some particular tissue problem.

The work which the Committee might with advantage undertake in connection with tissue metabolism ranges over an extremely large field, and, bearing this in mind, the Committee determined that their first duty was to lay the foundation for future work by the development of sound and fruitful methods, utilising for the purpose a limited number of tissues. This object has been now more or less obtained, and the Committee do not therefore propose to ask for reappointment. They recognise that there is need for further special research as to the metabolism of special tissues, but they consider that this may now be left to individual effort, aided by grants for specific purposes.

In presenting their final report it seems desirable to review some of the work which has been carried out during the last five years, and which has been rendered possible by the financial help afforded by the grants given to the Committee by the Association.

I. TECHNIQUE.

Apparatus.—The essential observations in an experiment on the gaseous exchange of an organ are three in number—the analysis of arterial blood, the analysis of the venous blood which comes from the organ, and the rate of flow of blood through it.

The analysis may be undertaken by one of three methods :—

1. The blood gas-pump.
2. The chemical method.
3. The differential method.

1. *The Blood Gas-pump.*—No new principle has been introduced, but extensive modifications have been gradually developed in technique in devising what seems to be the most convenient form of pump.

It was essential to have apparatus which will work quickly and with as little labour as possible. It has been found best to have four similar pumps, which can be rendered vacuous a day or two before the experiment. The blood is collected in long tubes of about 10 c.c. capacity. The froth chamber is fitted with a double-surface condenser filled with ice and salt. The mercury is raised in the pump by water-pressure. The pumps are used as follow: (1) For the venous blood from the resting organ; (2) for the arterial blood from the resting organ; (3) for the venous from the active organ; (4) for the arterial blood from the active organ.

2. The chemical method of analysing small samples of blood (1 c.c.) has been improved in a few manipulative details.

3. Much of the analysis may be saved by adopting the differential method, which gives a direct measurement of the difference between the quantities of oxygen (or carbonic acid) in the arterial and venous samples. This method, as well as being very rapid, is exceedingly accurate. In general it will be found best to use the differential method, and to test the accuracy of the results which it gives by the other two methods.

Anæsthetics.—The anæsthetic which is used requires careful consideration. At present it will be best to avoid the use of volatile anæsthetics (chloroform and ether) where the analysis is made by the blood gas-pump. Morphia is often undesirable, both on account of its deleterious effect on certain organs (the kidney) and on account of the deficient respiration which it produces. In cases where none of the anæsthetics mentioned can be used there remains urethane.

Clotting of Blood.—A constant source of solicitude is the tendency of the blood to clot in cannulæ and apparatus. Two general methods for the prevention of clotting seem useful.

1. In cases where there is a rapid flow of blood from a big organ the blood withdrawn may be received under oil into potassium oxalate. For this purpose an exact method of dilution has been devised.

2. In the case of small organs the animal may be given an injection of hirudin. The Committee have ascertained that this reagent has no specific disturbing influence on the gaseous contents of the blood.

The Measurement of Rate of Flow has usually been made by the direct observation of the time which the blood emerging from the organ takes to fill a tube of convenient size.

An indirect method which is valuable in certain cases, *e.g.*, the intestine, consists in placing the organ in a plethysmograph, damping the vein momentarily, and noting the graphic record of the increase in volume of the organ.

Perfusion with Saline Solutions.—In some cases it is convenient to measure the gaseous exchange of organs which are supplied with an artificial circulation of Ringer's or Locke's solution. For this purpose apparatus has been devised for the oxygen analysis of samples of 10 cubic centimetres each. The apparatus used has involved the elaboration of the 'capillary method' of gas analysis.

II.—The Results obtained in Individual Organs.

The following organs have been investigated by the Committee :—

The heart, the kidneys, the salivary glands, the pancreas, the intestines, and to some extent muscle. In addition to these a few preliminary experiments have been undertaken on the liver.

The Heart.—The amount of oxygen taken up by the heart varies with the activity of the organ. Adrenalin, atropine, and barium chloride increase the oxygen intake of the heart; stimulation of the vagus or administration of pilocarpine, chloroform, or potassium chloride reduces the quantity of oxygen which the heart requires.

The Salivary Glands.—The oxygen exchange of the submaxillary gland of the dog, the cat, and the rabbit has been the subject of numerous experiments. The metabolism of these glands is increased by stimulation of the chorda tympani. This increase is three or four fold when the stimulation is accompanied by a flow of saliva; when the gland is atropinised the increased metabolism is much smaller, and amounts in many cases to about 30 per cent. of the total metabolism.

The Pancreas.—In the dog intravenous injection of secretion causes a threefold increase in the metabolism of the pancreas, coupled with the flow of pancreatic juice.

The Intestines.—A study of the gaseous metabolism of the intestines has furnished positive results. The metabolism is much increased during absorption, whether of water or of peptone (dog).

The Kidney has been investigated in the dog and in the frog, the former by the blood gas method, and the latter by perfusion with Nager's solution. The following results have been obtained: Increase in the flow of urine, induced by the injection of salts, causes a threefold increase in the oxygen consumption of the dog's kidney, whether perfused through the renal portal vein or through the renal artery. The metabolism of the kidney is about twice as great when perfused through the renal artery as it is when perfused through the renal portal vein. By whichever path the perfusion fluid is led into the kidney, the metabolism greatly increases when the organ is secreting urine under the influence of diuretics.

There is no case of diuresis in either of the animals under observation without greatly increased metabolism.

Skeletal muscle was the only organ the gaseous exchange of which had been seriously studied by previous workers. The Committee have verified the coefficient of oxidation as determined by Chauveau and Kaufmann.

The production of lactic acid in muscle as the result of incomplete oxidation has been investigated. The production of lactic acid under anaërobic conditions varied with the time and was increased by heat, stimulation, &c.

III. *Comparison of Results obtained from Different Organs.*—Some results of general application have been gleaned from the study of the metabolism of individual organs :—

1. Increased vascularity does not of itself cause any change in the

oxygen consumption. This has been shown in the heart, the pancreas, the salivary glands, and the kidney.

2. Increased vascularity is associated with increased production of carbonic acid in such a way as to suggest the conclusion that some product of the metabolic activity of the organ—probably not CO_2 itself—causes vascular dilatation during increased function activity. This has been shown in the heart and the salivary glands.

3. A comparison of the 'coefficients of oxidation' (the quantity of oxygen used up per gramme of tissue per minute) varies for different organs when at rest. It is much higher for the glandular organs than for skeletal muscle. The following figures are known :—

Name of tissue	Animal	Coefficient of oxidation
Skeletal muscle (Chauveau & Kaufmann)	Horse	0·004 c.c.
"	Dog	0·0045 "
Cardiac muscle	Dog	0·01 "
"	Cat	0·01 "
Submaxillary gland	Dog	0·03 "
"	Cat	0·02 "
"	Rabbit	0·02 "
Pancreas	Dog	0·03 "
Intestine	Dog	0·02 "
Kidney	Dog	0·03 "

The following calculation would give some approximation to the oxidation taking place in the organs of a dog of 10 kilogrammes (1) when all the organs were (except the heart) resting ; (2) when all were active. The liver is calculated on the basis of other glandular organs—an exterpolation which seemed to be justified in the light of a couple of preliminary experiments :—

Organ	Weight	Rest		Activity	
		Coefficient	Quantity of oxygen absorbed	Coefficient	Quantity of oxygen absorbed
Skeletal muscle	3235 g.	0·004	12·9 c.c.	0·08	259 c.c.
Heart	68 "	0·03	2·0 "	0·08	5·4 "
Salivary glands	14 "	0·03	0·4 "	0·08	1·1 "
Pancreas	18 "	0·04			
Alimentary Canal	279 "	0·025	7·0 "	} 0·08	43·5 "
(Liver	264 "	0·03)	7·9 "		
Kidneys	44 "	0·035	1·5 "	0·95	4·2 "
			31·7 c.c.		313·2 c.c.

From the results given above it would appear that the rôle of muscle as the great regulator of heat production is played as much in virtue of the relatively small amount of oxidation which takes place in it when at rest as the relatively great amount during activity.

In bringing the inquiry to a close—at least as regards the more general aspects referred to in this report—the Committee wish to express their sense of the generous spirit in which the British Association has met the recommendations of the Physiological Section by affording that continual financial support without which the prolonged series of investigations could not have been prosecuted with success. The results already attained are, in the opinion of the Committee, of very considerable importance, since the inquiry deals with such fundamental problems as the nature of the chemical changes which occur in the isolated tissues of the body, the alteration in such changes during tissue activity, and the technique by means of which such problems may be further studied under special conditions. It is scarcely possible to exaggerate the physiological importance of such investigations, and it is to be hoped that the present inquiry may be of service, not merely by its actual results, but still more by future achievements in this field.

List of Papers which embody so much of the work of the Committee as has already been published.

'The Oxygen Exchange of the Pancreas,' *Journal of Physiology*, vol. xxxi. p. 491.
'The Gaseous Metabolism of the Kidney,' *ibid.*, vol. xxxii. p. 18.
'The Gaseous Metabolism of the Kidney,' *ibid.*, vol. xxxiii. p. 52.
'The Estimation of the Oxygen dissolved in Small Quantities of Salt Solutions,' *ibid.*, vol. xxxiv. p. 306.
'The Gaseous Metabolism of the Mammalian Heart,' *ibid.*, xxxv. p. 182.
'The Velocity and Nature of the Blood emerging from the Submaxillary Gland,' *ibid.*, vol. xxxv. p. xxix.
'The Effect of Hirudin on the Gases of Arterial Blood,' *ibid.*, vol. xxxvi. p. 275.
'The Analysis of Oxygen and Carbonic Acid contained in Small Quantities of Salt Solutions,' *ibid.*, vol. xxxvi. p. 405.
'The Mechanism of Vasodilation in the Cat's Submaxillary Gland,' *ibid.*, vol. xxxvi. p. liii.
'A Differential Method of Blood Gas Analysis,' *ibid.*, vol. xxxvii. p. 12.
'Gaswechsel des Dünndarms während der Reabsorbtion von Witte Pepton,' *Deutsch. med. Wochensch.* Jahrg. 33, p. 1566.
'Gaswechsel des Dünndarms während der Reabsorbtion von Koch Salzlösungen verschiedener Stärken,' *ibid.*, p. 1566.
'Gaswechsel in der Speicheldrüse der Kätze,' *ibid.*, p. 1566.
'Zum Lehre vom Blutgaswechsel in den verschiedenen Organen,' *Ergebnisse der Physiologie.* Siebender Jahrg., p. 699.

The Ductless Glands.—Report of the Committee, consisting of Professor SCHÄFER (*Chairman*), Professor SWALE VINCENT (*Secretary*), Professor A. B. MACALLUM, Dr. L. E. SHORE, *and* Mrs. W. H. THOMPSON. (*Drawn up by the Secretary.*)

THE work of the Committee has been divided as follows: Mrs. W. H. Thompson has been investigating the comparative anatomy and histology of the thyroids and parathyroids. Drs. F. A. Young and J. E. Lehmann have been performing some experiments on the internal secretion of the suprarenal capsules of the dog. Dr. J. H. Leeming has been occupied with the study of the medulla of the suprarenal capsule and the question of its relation to other similar tissues in the body.

Mrs. Thompson reports that her work is by no means complete, but that all the evidence collected from a study of the thyroids and parathyroids throughout a wide range of the animal kingdom supports the view held by Vincent and Jolly and by Forsyth, viz., that thyroids and parathyroids are not separate and independent organs, but are very intimately related, the essential histological elements being practically identical in the two structures.

Drs. F. A. Young and J. E. Lehmann give a preliminary account of some experiments with the blood-stream from the suprarenal glands of the dog.

Cybulski and Biedl found that the blood of the suprarenal vein raised the blood-pressure when injected intravenously. Salvioli and Vezzolini showed that the blood from the suprarenal vein acts like suprarenal extract, but weakly. The blood from the suprarenal vein produces much more effect upon the excised eye of the frog than does ordinary blood. The water extract of the dried blood gives distinct pressor effects.

The present series of experiments was instituted in order to obtain, if possible, evidence of a more direct nature of the fact of internal secretion from the suprarenal capsule. An attempt was made to dam back any secretion which the glands may pour into the blood-stream and after an interval to remove the obstruction and allow the accumulated secretion to flow into the general circulation.

The blood-pressure was recorded in the usual manner from the carotid artery; the glands were exposed through an abdominal incision, and a double ligature passed beneath the organ on each side. The ligatures were tied on each side of the gland above the vein so as to form two pedicles, and were left in place for from 10 to 30 minutes and then released.

Out of a total of eight experiments, in three there was no effect on the blood-pressure; in two there was a slight rise after releasing the ligatures; in the remaining three there was a decided rise of the pressure (similar to that which follows the injection of suprarenal extract), lasting about three minutes. In one experiment the effect was repeated by tightening the ligatures a second time and again releasing them.

It must be noted that the fall of blood-pressure during the time that the ligatures were applied was only slight, and this is what one would expect.

Numerous control experiments have been performed in order to guard against any fallacy arising from stimulation of nerves or other adventitious circumstances.

If further experiments should confirm the results of the present series, it seems that we have very positive evidence that the pouring of the adrenal secretion into the circulation is one of the factors which maintain the normal blood-pressure, a view which of course was implied in the internal-secretion theory of the organs put forward by Oliver and Schäfer at the time of their discovery of the powerful effects of suprarenal extracts.

The experiment here described is a modification of one originally suggested by Professor Schäfer, but which we believe has not up to the present been carried out.

Dr. Leeming finds, much to his surprise, that the cells staining brown with bichromate of potassium (and hence considered to be of the same nature as suprarenal medulla), which have been described in various regions of the body, are so rare or so difficult to reveal that so far he has failed altogether to verify their existence. He has carefully examined a number of dogs, cats and kittens, and rabbits, and, though he has closely followed Kohn's technique in every detail, yet he has been up to the present unable to demonstrate the presence of 'chromaffin' cells in any tissue except in the medulla of the suprarenal capsule.

The Committee ask to be reappointed with a grant of 30*l.* By accident a considerable part of last year's grant remained undrawn, although expenditure had been incurred which it was intended to meet. This will be paid out of the next grant, if renewed.

The Effect of Climate upon Health and Disease.—Third Report of the Committee, consisting of Sir LAUDER BRUNTON (*Chairman*), Mr. J. BARCROFT *and* Lieut.-Col. R. J. S. SIMPSON (*Secretaries*), Colonel Sir D. BRUCE, Dr. S. G. CAMPBELL, Sir KENDAL FRANKS, Professor J. G. MCKENDRICK, Sir A. MITCHELL, Dr. C. F. K. MURRAY, Dr. C. PORTER, Professor G. SIMS WOODHEAD, *and the* Heads of the Schools of Tropical Medicine of Liverpool, London, and Edinburgh.

THE following is a complete list of the members of the Committee, including the co-opted members. The names of those who are not members of the British Association are indicated by an asterisk :—

*Aldridge, Lieut.-Col. A. R., R.A.M.C., Simla, India.
*Allbutt, Sir T. Clifford, K.C.B., F.R.S., Cambridge.
*Anderson, Dr. Barcroft, East London, Cape Colony.
*Ashe, Dr. E. O., Kimberley, Cape Colony.

*Bain, Dr. Wm., Harrogate.
*Balfour, Prof. A., Khartoum.
Barcroft, Joseph, Cambridge.
*Benedict, Prof., Middletown, Conn., U.S.A.
Bohr, Prof. C., Copenhagen.
*Boobbyer, Dr. Philip, M.O.H., Nottingham.
*Bourguignon, Dr., Matadi, Congo Free State.
Branfoot, Surgeon-General, A.M., C.I.E., I.M.S., India Office.
*Broden, Dr., Leopoldville.
Bruce, Colonel Sir D., C.B., F.R.S., London.
Brunton, Sir Lauder, Bt., F.R.S., London.
*Bulloch, Dr. Wm., London.
*Bulstrode, Dr. H. Timbrell, Local Government Board, S.W.
*Bumm, Präsident, Berlin.

Campbell, Dr. S. G., Durban, Natal.
*Cantlie, Dr. James, London.
*Charles, Sir R. Havelock, K.C.V.O., I.M.S., London.
*Chittenden, Prof. R. H., New Haven, Conn., U.S.A.
*Clarke, Dr. W. G., Bulawayo.
*Clemow, Dr. F. G., Constantinople.
*Clippingdale, Dr. S. D., British Balneological and Climatological Society, London.
*Cumming, Hamilton, Torquay.
Currie, Dr. O. J., Pietermaritzburg.
*Curtis, Dr. H., London.
Cushny, Prof. A. R., F.R.S., London.
*Dixon, Prof. W. E., Cambridge.
Douglas, Capt. H. E. N., V.C., D.S.O., India.
*Dunbar, Sir Wm. C., Bt., C.B., Registrar-General, London.
*Dunlop, Dr. J. C., Edinburgh.
Dunstan, Prof. Wyndham, F.R.S, London.

*Ellis, Sir H. M., K.C.B., K.H.P., late Director-General Naval Medical Service.
*Etienne, Dr., Boma, Congo Free State.
*Evatt, Surgeon-General G. J. H., C.B., Camberley.
*Ewald, Prof. A., Berlin.

*Fichet, Prof., Liège.
*Fox, Dr. Fortescue, British Balneological and Climatological Society.
*Franklin, Surgeon-General Sir B., K.C.I.E., London.
Franks, Sir Kendal, C.B., Johannesburg.
Fraser, Sir Thos. R., F.R.S., Edinburgh.

Gamgee, Prof. A., F.R.S., London.
*Grabham, Dr. M. C., Madeira.
*Greenwood, Dr. M., jun., London.
*Gregory, Dr. A. J., Cape Town.

*Hann, Prof. J., Vienna.
*Hardy, W. B., F.R.S., Cambridge.
*Harford, Dr. C. F., Leyton.
*Hay, Prof. Matthew, Aberdeen.
*Heiberg, Dr. Inge, Boma, Congo Free State.
*Hendley, Col. T. H., C.I.E., I.M.S., London.
Herbertson, Dr. A. J., Oxford.
*Herdman, Dr. Ronald, Filabusi, near Bulawayo.
*Hill, Dr. Leonard, F.R.S., London.
*Hyslop, Dr.. J, D.S.O., Pietermaritzburg.

*Jaffé, Dr., Berlin.

Keltie, Dr. J. Scott, F.R.G.S., London.
*Keogh, Sir A., K.C.B., K.H.P., Director-General, Army Medical Service, London.
*Kerp, Prof., Berlin.
*King, Col. W. G., C.I.E., I.M.S., Sanitary Commissioner, Burma, India.
Kronecker, Prof. Hugo, Berne, Switzerland.

*Langgaard, Prof., Berlin.
Lankester, Sir E. Ray, K.C.B., F.R.S., London.
Latham, Baldwin, M.Inst.C.E., London.
Lempfert, R. G. K., London.
*Leslie, Lieut.-Col. J. T. W., I.M.S., India.
Liversidge, Prof. A., F.C.S., Sydney, N.S.W.

MacAlister, Principal, Glasgow University.
McCulloch, Major T., R.A.M.C., India.
Macdonald, Dr. J. S., Sheffield.
*McGregor, Sir Wm., G.C.M.G., C.B., F.R.S., Newfoundland.
McKendrick, Prof. J. G., F.R.S., Glasgow.
*Mackenzie, Dr. Leslie, Edinburgh.
*Manners, Dr. W. F., Calabar, West Africa.
*Manson, Sir Patrick, K.C.M.G., F.R.S., London.
*May, Deputy-Director-General A. W., Naval Medical Service.
*Meek, Lieut.-Col. J., R.A.M.C., Simla, India.
*Melville, Lieut.-Col. C. H., R.A.M.C., London.
Mitchell, Sir A., K.C.B., Edinburgh.
*Mitchell, Dr. Weir, Philadelphia.
*Mitchell, Dr. J. A., Colonial Office, Cape Town.
*Moffat, Dr., C.M.G., Uganda, Central Africa.
*Moore, Sir John, Dublin.
*Morgan, Major J. C., R.A.M.C., India.
*Mosso, Prof. Angelo, Turin, Italy.
*Müller, Dr. Franz, Berlin.
*Murison, Dr. P., Public Health Department, Durban, Natal.
Murray, Dr. C. F. K., Kenilworth, Cape Colony.

*Nuttall, Prof. G. H. F., F.R.S., Cambridge.

Oliver, Prof. T., Newcastle.
*Osler, Dr. T. H., Cape Colony.
Osler, Prof. Wm., F.R.S., Oxford.
*O'Sullivan, Col. D., R.A.M.C., India.

*Pagliani, Prof., Turin, Italy.
*Pearce, Major C. R., I.M.S., India.
*Pembrey, Dr. M. S., London.
*Phillips, Dr. L. P., Cairo.
*Pinching, Sir Horace, K.C.M.G., Cairo.
Porter, Dr. C., Johannesburg.
Prain, Lieut.-Col. D., C.I.E., I.M.S., Kew.

*Raymond, Major G., R.A.M.C., Wellington, India.
Reymond, Prof. René du Bois, Berlin.
*Robertson, Dr. John, Birmingham.
*Rochfort-Brown, Dr. H., Pietermaritzburg.
*Rogers, Major Leonard, I.M.S., Calcutta.
Ross, Major Ronald, C.B., F.R.S., Liverpool.
*Rost, Dr. E., Berlin.
Ruffer, Dr. E. A., C.M.G., Ramleh, Egypt.

*Salmond, Dr. W., Ladysmith.
*Sanders, Dr. A. W., Pretoria.
*Schilling, Dr., Berlin.
*Scott, Major B. H., Edinburgh.
Scott, Dr. R. H., F.R.S., London.
Shaw, Dr. W. N., F.R.S., London.
*Sims, Dr. A., Matadi, Congo Free State.
*Smith, Major Fred., D.S.O., R.A.M.C., India.
*Spencer, Dr. Walter, Sydney, N.S.W.
*Stephens, Dr. J. W. W., Liverpool.
*Strangeways, Dr. T., Cambridge.
*Strong, Surgeon-Capt. E. H., Bulawayo.
*Sutherland, Dr. S., London.
*Symons, Dr. W. H., Bath.

*Tatham, John F. W., London.
*Theiler, A., Pretoria.
*Thomson, Dr. Theodore, C.M.G., London.
*Tirard, Dr. N. I. C., London.
Todd, Dr. J. L., McGill University.
Turner, Dr. G., Pretoria.

*Usmar, Dr. G. H., Bloemfontein.

*Verdick, Le Commandant, Boma, Congo Free State.

Wager, Harold, F.R.S., Leeds.
*Walford, Dr. E., Cardiff.
*Walker, Dr. G. Thomas, F.R.S., Simla India.

*Ward, Dr. A. B., Bloemfontein.
*Watkins, Dr. A. H., Kimberley.
*Weber, Dr., Berlin.
*Weber, Dr. Parkes, London.
*Welsh, Fleet-Surgeon, R.N., London.
*Will, Lieut.-Col. J., R.A.M.C., British East Africa.
*Woekoff, Prof., St. Petersburg.
Woodhead, Prof. G. Sims, F.R.S., Cambridge.
*Woodhouse, Lieut.-Col. T. P., R.A.M.C., India.
*Wutzdorff, Dr., Berlin.
*Yule, Dr. Pratt, Bloemfontein.
*Zuntz, Prof. N., Berlin.

The study of the effect of climate upon health and disease for which the Committee was appointed can be pursued by two methods—the statistical and the experimental. In each case the work may be subdivided into the preliminary consideration of the nature of the data which would afford material for investigation, and the provision for the acquisition and discussion of these data.

In order to facilitate the collection of statistics of climate and disease upon co-ordinated lines, forms for the tabulation of data with explanatory memoranda were prepared last year. Specimen copies of these forms and memoranda have been forwarded to each member of the Committee, and to others as indicated in last year's report. The memoranda are printed as appendices to this report.

An inquiry is being conducted by the Committee into the coincidence of diseases of the circulatory, nervous, and digestive systems respectively with influenza in different epidemics of that disease. In the prosecution of this inquiry the Committee have to acknowledge its indebtedness to two co-opted members of the Committee, viz., the Registrar-General, Sir Wm. C. Dunbar, Bart., C.B., and Dr. J. F. W. Tatham, Superintendent of Statistics, General Register Office, for their valuable assistance, without which the inquiry would have been impossible.

The Committee have no funds for the payment of the scientific staff and clerical assistance that would be necessary for the organisation and prosecution of researches of this character upon a permanent basis. Although it can look forward to the continuance of the active support afforded by Government departments and public bodies, such support cannot take the form of money grants to the Committee. The grant of the Association is absorbed in secretarial and incidental expenses, and any expense incurred in the prosecution of researches falls upon individual members of the Committee.

The Committee cannot therefore contemplate extensive operations in the direction of the compilation and discussion of the meteorological and medical data, which would, in fact, afford sufficient work for a separate institution.

There are however already in existence, within the knowledge of various members of the Committee, large accumulations of statistics and other data bearing upon various questions of climate and health, which might form the subjects of valuable essays by competent students who have time and opportunity for the study of the data, and special aptitude for work of this nature. The Committee are of opinion that some of these questions might be treated successfully as theses for the degree of M.D., provided that the advice of persons who have devoted attention to one or other aspect of the problems involved could be secured. They have been in communication with the heads of various Universities and medical schools with reference to this suggestion, and have received a number of encouraging replies. They have accordingly drawn up a preliminary list of subjects which might serve for this purpose and which might suggest others. They have placed against the several grouped subjects the names of those members of the Committee who are specially conversant with some of the aspects of the various questions and are willing to give advice and assistance to anyone who contemplates an analysis of the available data.

The Committee will be glad if anyone who is willing to undertake the preparation of a thesis upon any of the subjects mentioned, or upon some similar subject, will place himself in communication with Sir Lauder Brunton, the Chairman of the Committee.

Subject	Members willing to give Advice
1. The difference in symptoms, sequelæ, and pathology between sunstroke and heat apoplexy. 2. The effect of clothing and protection of the eyes as a prophylactic against sunstroke and in keeping down body temperature. 3. The effect of different materials and colours in dress on comfort and health. 4. The racial incidence of sunstroke. 5. The geographical distribution of Mediterranean fever in Europe. 6. The materials of which houses are built, especially roofs, in ameliorating the rigours of climate and in improving health.	Lieut.-Col. R. J. S. Simpson. Deputy Director-General A. W. May.
7. The incidence of gouty kidney with traces of albumen. 8. Food in relation to climate. 9. The effect of alcohol in hot and cold climates. 10. Soil dampness in relation to tuberculosis.	Professor R. H. Chittenden. Sir Lauder Brunton. Professor W. E. Dixon.
11. The general effect of soils on health. 12. Modification of climate of towns, &c., by local conditions, such as between the Plat and City at Hong Kong. 13. The relative values of high and low altitudes in promoting the arrest of pulmonary tuberculosis. 14. The relation of rainfall to the prevalence of diphtheria. 15. Bibliography of the relation of meteorological conditions to the seasonal prevalence of communicable and non-communicable diseases. 16. Town smoke in relation to health.	Dr. H. T. Bulstrode. Dr. J. Cantlie. Dr. S. D. Clippingdale. Dr. H. R. Mill. Sir A. Mitchell. Dr. W. N. Shaw. Dr. J. F. W. Tatham. Dr. J. J. S. Teale. Dr. F. Parkes Weber.
17. The possibility of expressing in simple mathematical terms the combined climatic value of temperature and humidity.	Dr. W. H. Hamer.

The experimental side of the Committee's work stands on a different footing. Experiments of the necessary type can be performed—often with simple apparatus—not only in the laboratories of medical schools, but in ordinary practice, and researches of this character might also serve for M.D. theses. The following subjects have also been suggested for experimental researches. Appended to each subject is the name of one or more members of the Committee who would undertake to advise those desirous of working in one of the directions indicated :—

Subject.	Members willing to give Advice
1. The determination of body (rectal) temperature under different conditions of atmospheric temperature and moisture. 2. Racial variations in temperature.	Dr. M. S. Pembrey. Mr. J. Barcroft. Dr. Fortescue Fox.
3. The relation of sunstroke to blood-pressure. 4. Racial variations in blood-pressure.	Sir Lauder Brunton.
5. The physiology of skin secretion. 6. The effect of light on perspiration.	Professor W. E. Dixon.

One research has so far yielded suggestive results. The rectal temperatures of the members of the King's College Second Boat have been systematically taken before and after practice on several successive days. The rise has been smaller in most cases than previous researches has indicated. There would seem to be a considerable personal equation, as shown by the temperature of two of the men—No. 5 and stroke.

Changes in Temperature (Fahrenheit) induced by rowing.

Date.	May				June		
	27	28	29	30	1	2	3
	°	°	°	°	°	°	°
No. 5 . .	+1·7	+1·8	+1·9	+1·7	+2·1	+1·7	+2·1
Stroke . .	−0·4	−0·2	−1·4	−1·1	−0·5	−0·0	−0·4

After May 28 the rowing was performed at temperatures varying between 71° and 75° F. It is proposed to undertake similar observations in the cold weather of the Lent Term. The Committee take this opportunity of expressing their thanks to the members of the crew who have co-operated in this research.

No progress has yet been made with the preparation of the bibliography mentioned in the first report of the Committee.

The Committee ask for reappointment, with a grant for secretarial and incidental expenses.

APPENDICES.

Appendix I.

Memorandum on the Climatic and other Geographical Data for the Investigation.

The success of any specific inquiry into the relations between physical environment and health or disease depends ultimately upon the initiative and skill of the person who conducts it. The precise course of the inquiry must be regulated by the particular circumstances of the case, so that no rules of general application can be laid down. It may be necessary for the investigator to organise for himself the special series of observations required for the particular object which he has in view, but at the same time it is well to remember that there are already in existence extensive organisations in the form of official departments or scientific societies which are engaged in the collection of climatic, demographic, and other geographical data for general purposes, and that advantage may be taken of these collections either for the direct purpose of the inquiry or for the discussion of important collateral issues.

Further it may be remarked that the connection between the incidence or development of disease and the physical environment is often indirect. Climate may be regarded as the dominant variable, but its effects may be produced through consequent alterations of surface and ground water, or through its influence upon plants or animals, or in consequence of the conditions of the ground and of the human settlements upon it.

The compilation of a special body of data concerning all these points is generally beyond the power of the investigator with limited time and opportunity at his disposal, and the following suggestions are drawn up to enable him to bring the results obtained by the ordinary agencies for collecting such information into co-operation with those obtained in the course of the special inquiry.

The organisation of meteorological observations is well advanced. It is therefore possible to give an effective statement as to the nature and extent of the data which are already available and where they may be found. The information about the other factors cannot be so easily dealt with. Demographic statistics and other information of an official character can be obtained from the reports of various Government Departments, but there is an enormous body of information on other points which must be sought in the libraries and collections of scientific societies. In Section II. of this memorandum the various heads of information are enumerated, and a brief indication is given of the sources which are most likely to prove useful.

Appendix I (*a*).

Climatic Data.

The preparation, collection, and publication of meteorological data have been conducted, more or less effectively, for a long series of years and for nearly all parts of the world, in accordance with practices which have been codified and organised by international agreement. The meteorological data thus compiled are prepared for publication, principally in the form of monthly averages. Daily values are published for comparatively few of the whole number of meteorological stations. In those cases in which daily values are required, inquiries should be directed to the meteorological authorities of the countries concerned.

It is necessary that in preparing vital statistics for comparison with climatic statistics, these facts should be borne in mind at the outset, so that comparisons may be, as far as possible, conducted for months, or combinations of months ; otherwise the investigator may find himself face to face with the practically impossible task of recovering the original observations and recompiling them for his own purposes.

In complete form, the organisation of meteorological stations is designed to afford data from which the following meteorological elements can be obtained :—

1. The mean barometric pressure. In order that observations may be strictly comparable, the means should be determined from twenty-four hourly readings. In most cases the only observations available are those taken at two or more fixed hours during the day, and a correction must be applied to the means determined from these observations, in order to reduce them to the true daily means. The amount of this correction can be determined from the records of the stations of the first order, where such exist. Stations of the first order are those which are provided with self-recording instruments, or at which personal observations are made every hour.

2. The mean air temperature. To render observations strictly comparable, the means should be determined from twenty-four hourly readings. Means determined from observations at fixed hours can be reduced to true daily means by the application of a correction which can be determined from the records of first-order stations, where such exist.

3. The mean maximum and mean minimum temperature, and the absolute extremes of temperature with the dates of their occurrence.

4. The mean pressure of aqueous vapour and the mean relative humidity, determined from readings of dry and wet bulb thermometers.

5. The total rainfall, and the maximum fall in one day, with the date of its occurrence.

6. The mean amount of cloud, expressed as a decimal fraction of the sky covered.

7. The frequency of days of rain, snow, hail, thunderstorm, clear sky, overcast sky, and, for some stations, fog.

8. The frequency of winds from each of eight points of the compass, and information concerning wind force.

9. Information concerning temperature of the soil, grass minimum temperature, and solar radiation temperatures. These elements are not included in the international scheme, but information about them is given in some cases.

These means, with such modifications as are imposed by the circumstances of the several cases, form the basis of the monthly summaries which are so largely represented in meteorological publications. Information as to the diurnal variation of the various elements beyond what is indicated in the foregoing statement, is not given as a rule in meteorological tables, but for a number of stations it could be supplied on application to the Meteorological Authorities.

Appendix I (*b*).

The examination of the relation between disease and climate may be conducted upon one or other of two methods :—

(*a*) The chronological method, by which the data for a single locality are examined for periodic or secular changes.

(*b*) The topographical method, by which the data are considered with regard to geographical distribution,

or by a combination of both (*a*) and (*b*).

The application of climatological and other data upon these two methods may be considered separately.

(*a*) The Chronological Method.

The monthly data for any station or country enumerated in the summary mentioned in the next following paragraph with sufficiently long records are available for the study of questions upon this method. The only question which arises is the important one of the reference of current values to averages, in consideration of the fact that different stations have records of different duration. In order to make the data generally available, monthly averages should be given for the periods of five years, indicated by the unit figures 1 to 5 and 6 to 0, *e.g.*, 1901–05, 1906–10, so that groups of corresponding duration may be combined without difficulty, to form a uniform system of averages for reference.

(*b*) Topographical Method.

Appendix VII. of the report of the Committee of the Meteorological Office for the year 1905–6 gives a brief summary of the published material which is available from each of the areas into which the world is divided in the International Catalogue of Scientific Literature. The data can be consulted at the Meteorological Office. A list of other Central Offices where Meteorological publications are collected is given below on pp. 455 and 456.

Publications classified in that summary under the heading 'Meteorological Registers General' are almost all in the form of monthly averages. In the majority of cases the form used is based on that adopted by the Permanent International Meteorological Committee, as suitable for use at stations of the second order. (For details see below.)

In localities where it is decided to start fresh observations a similar form should be adopted. Form 19 of the Meteorological Office may be used for recording the observations, but it is desirable, for the adequate study of questions connected with the humidity of the atmosphere, that provision should be made for an observation in the early afternoon. The following combinations of hours have been recommended by the Permanent International Meteorological Committee, as suitable for use at second-order stations in Europe :—

6 a.m.	2 p.m.	10 p.m.	8 a.m.	2 p.m.	8 p.m.	with minimum temperature	8 a.m.	8 p.m.
7 „	2 „	10 „	9 „	3 „	9 „		9 „	9 „
7 „	1 „	9 „	10 „	4 „	10 „		10 „	10 „
7 „	2 „	9 „						

In the British Isles, observations at stations of the second order are taken at 9 a.m. and 9 p.m. The Committee of the British Association, which in 1892 prepared a book of 'Hints to Meteorological Observers in Tropical Africa,' recommended the combination 7 a.m., 2 p.m., and 9 p.m. for adoption in Tropical Africa.

The selection of times has been made with a view to the determination of the true daily mean temperature from the observations at fixed hours. For other elements and for other climates, other combinations of hours might prove to be more suitable. The question can only be dealt with effectively by a study of the records from first-order stations.

Monthly summaries of the observations should be prepared in the International Form, of which the Monthly Report of the Meteorological Office may be taken as a specimen.

In cases where the complete scheme of observations is impracticable or undesirable, a form similar to Meteorological Office Form No. 34 should be used for recording the observations, but provision should be made if possible, for including observations of wind. The abridged summaries, given in the Monthly Report of the Meteorological Office, may be taken as a specimen of the form for publishing these data. The observations of wind should be summarised in the manner shown in the full monthly summary.

It is a recognised principle in meteorological publications that the values of the various meteorological elements are arranged in parallel vertical columns. Reading downwards any column gives the values of the elements either for various stations, or for successive days, or for consecutive months, years, or lustra of five years, as the case may be.

It is highly desirable that private observers who undertake meteorological observations should arrange their observations upon the recognised plan, and forward copies of them to some central meteorological institution in order that the results may be made available for use by investigators.

Appendix I (c).

Other Factors to be considered.

The following information should also be supplied, in addition to the meteorological conditions :—

Physical Structure and Surface Conditions—

1. Physical configuration in contours, if possible.
2. Geological formation: (*a*) surface, (*b*) solid.
3. Soil, sub-soil, and rock: (*a*) composition, (*b*) porosity.
4. Ground water: (*a*) composition, (*b*) variation of level, (*c*) other movements. Note relation to seasonal rainfall.
5. Rivers: (*a*) depth of water, (*b*) rate of flow, (*c*) seasonal variations, (*d*) sources of pollution.

Biological Conditions—

1. Vegetation. (Note especially the distribution of wood, grass, cultivated, waste, marsh, and bare land.)
2. Any notes on insect or other animal life of the locality in relation to health.

Human Conditions—

1. Population of area.
2. Density of different sections in terms of (*a*) people per acre, (*b*) inhabited houses per acre. } These are generally the subjects of official inquiry.
3. Distribution of occupations.
4. Distribution of birth-rates and death-rates.
5. Typical diets of different sections of the community.
6. Water-supply: (*a*) source of supply above or below ground water-level, (*b*) nature of water—hard, soft, saline, variations with seasons.
7. Disposal of refuse, and more particularly of sewage.
8. Any fluctuations in employment, with special notes on effects of strikes or famines (when they occur).

Appendix II. contains a list of Learned Societies and Institutions which collect and publish information bearing upon a number of the points enumerated herein.

Those who have the opportunity of contributing to the general fund of information which may prove useful in inquiries should consult the 'Hints to Travellers' of the Royal Geographical Society or the 'Admiralty Manual of Scientific Inquiry,' and should be careful to communicate the results of their investigations for publication in the most generally accessible forms.

For geographical conditions reference should be given to standard books, papers, and maps, if such exist. If these are inadequate, supplementary notes and maps should be forwarded.

W. N. Shaw.
A. J. Herbertson.

Appendix II.

Data relating to Disease.

(*a*) Nomenclature.

The list of diseases given in the printed forms supplied for the record of cases and deaths from disease is based on the official 'Nomenclature of Diseases' of the Royal College of Physicians, edition 1906. Where an observer is not in possession of, or has not access to, this 'Nomenclature,' he will be provided with a copy on application to the Central Committee.

Those diseases only have been printed in the forms which appeared for one reason or another to lend themselves to the purposes of this investigation, or concerning which fuller information as to distribution and prevalence is desirable, which should be obtainable without difficulty in the course of this inquiry.

Synonyms have been inserted in most cases in which they are used in the 'Nomenclature,' and in all in which any doubt could arise as to the exact nature of the disease designated by the official title. The number prefixed to each disease is that allotted to it in the 'Nomenclature,' and a reference will therefore clear up any difficulties of description.

But the printed list is not intended to be exclusive; space is left at the end of the list under each system for the insertion in manuscript of any other disease which an observer is prepared to report on, and in fact certain systems have been allotted space for this purpose, though no diseases have been printed under the headings.

The names of symptoms or of local manifestations should not be used as descriptions; the case should be inserted under the general heading of the cause to which these conditions are due. In the special case of anæmia (No. 61), included in this list for purposes of comparison, this term should only be used where it has proved impossible either to differentiate the type or to discover the cause.

While it is highly desirable that the officially recognised titles should be used for the disease under report in order that all doubt and difficulty may be removed, yet where the observer either has not access to the complete list or for some reason finds it unsuitable, there is, of course, no objection to his using any terminology that may appear to him satisfactory, provided always that it is used consistently, and that he gives such information as may enable the Committee to recognise the disease on which he is reporting.

(*b*) Disease statistics of population.

Statistics concerning the prevalence of or the mortality from disease are of little value by themselves, nor can their variations be accurately compared with climatic changes, or, indeed, with any other variable, till their primary relationship to the population from which they are drawn is established. Further, the incidence of a mortality is often selective in the same race, determined usually by age, often by occupation, sometimes by sex.

The requirements for the satisfactory comparison of disease data may be set forth in tabular form :—

Total cases of disease Total deaths from disease	Require . .	Total population from which they were drawn.
Cases by ages Deaths ,,	. . . . ,, . .	Population by ages, and possibly total deaths by ages.
Cases by sex Deaths ,,	. . . . ,, . .	Population by sex.

Where the disease appears to be limited, chiefly or entirely, to one section of the population, these statistical details should be given for the sectional as well as for the total population.

Racial differences in incidence and mortality are most important, and can only be elucidated by comparative statements in which all the particulars enumerated above are comprised.

It may sometimes be impossible to obtain exact statements as to age distribution of the population, but the best available information should be given. There may be in certain localities a temporary change in the age distribution of the population, where for religious, economic, or climatic reasons, the tide of immigration (usually mainly of young adults) flows at regular or irregular intervals. Probably this in most cases affects the annual rather than the monthly ratios, but it is a point which is worthy of consideration.

(*c*) Disease statistics.

These fall into two classes :—

(i) Where cases and deaths are recorded.

These include statistics from hospitals (civil, naval, and military), and from prisons and gaols. The published data from these sources usually give annual values for all and monthly for certain diseases. They include, of course, all cases and deaths which come under observation ; they are complete as far as they go. But the relation of these hospital cases to the population varies. In naval and military statistics the whole sickness of the navy or army is dealt with, hence the actual incidence rate on the population is known. The deaths, however, do not represent the total mortality due to sickness contracted in the service, as a certain small proportion of men die after invaliding out of the service from disease actually contracted in the service.

Civil hospitals deal only with a part of the sickness of the population, and the relation of this part to the total sickness of the population is a very variable quantity. Hence, normally, the number of attacks in the civil population is not known. The deaths in hospital also do not represent the true death-rate on the hospital population, as a certain proportion die after discharge from hospital.

In the special case of notifiable diseases we have, on the one hand, the total cases notified, and, on the other, the total deaths from each disease. One may assume that the fatal cases are notified, and that the total mortality on population is approximately correct: but it does not appear that the attack-rate calculated from the cases notified can always be accepted as accurate, or that two attack-rates in different localities are comparable, as there are considerable differences in different areas in the carrying out of the process of notification, especially abroad.

Practically, where accurate methods of incidence are required, and of mortality in acute disease, we have only the naval and military statistics to depend on. The records from prisons and gaols are more difficult of classification; certainly the total sickness of the population is dealt with, but the periods of 'exposure to risk' vary so much as to complicate matters. The records from the Indian (and from some Colonial) gaols are, however, extremely valuable in spite of this complication.

In all these cases the number of fresh attacks, as distinct from relapses, in such diseases as, *e.g.*, malarial fever and dysentery, should be noted; special records are usually necessary to elucidate this point, which is most important.

(ii) Where deaths only are recorded.

These are available, with varying degrees of accuracy, in all civilised countries. They form in many cases the only available records which relate to the whole, or, indeed, to any part of the population. They are, or can be made, available by age groups. Unfortunately, they have not all the same degree of accuracy; in the younger or less civilised countries the case often ends fatally without the cognisance of a medical man, and a medical certificate is not always obligatory, as indeed it often could not be obtained. Hence the deaths cannot be properly enumerated for statistical purposes; it is often not possible even to guess from the entry in the register what the cause of death may have been. Again, even where a medical certificate has been furnished the cause of death is too often described in vague or even misleading terms. The inquirer must often examine the register himself, and as conscientiously as possible eliminate and reconstruct. This reconstruction is, of course, a dangerous process; it can only give possibilities, or at most probabilities. But in some instances the true meaning of the death certificate is perfectly obvious, especially where the inquirer has local knowledge.

(*d*) The compilation of statistical tables of disease.

The useful periods are :—

(i) The week. Probably only useful in epidemic disease, or where a disease has a distinct seasonal variation of short period. Except for the United Kingdom there are no regular meteorological tables with which to compare these weekly results; the observer must then re-compile either (*a*) the daily meteorological data, to suit his weekly table, or (*b*) compile a monthly disease table from his daily records, as the weekly tables will not of themselves give monthly tables. The former is certainly the more useful process in the conditions in which a weekly disease record is wanted; the second process defeats the purpose of the weekly record; but in the end both weekly and monthly tables will usually be required.

(ii) The calendar month.

(iii) The year.

(iv) The quinquennial period: A group of the monthly values for five years, *e.g.*, 1901–5.

These are directly comparable with normal meteorological tables.

The monthly values are sufficiently close for nearly all purposes, and they are also less liable to adventitious error than the weekly record, where, except during an epidemic, or where the observer has an unusually large population to deal with, accidental causes may have an important influence on the weekly variations. From the monthly tables the compilation of the other tables of longer period is a simple matter.

The object of this memorandum is to inform observers of what material is available and in what form, and to suggest the general lines which new investigations should follow in order that they may be comparable with existing records. If the suggestions in this memorandum are followed, observers will usually find the interim results which they may obtain will permit of easy rearrangement if that should prove necessary for purposes of comparison. This is important, because (especially abroad where reference libraries are scarce) it may happen that the opportunity for observation must be seized at once or lost, while it is impossible to ascertain immediately what has already been done. The observer may in such a case compile his results on the lines indicated above, while he is at the same time seeking information as to existing material on the subject.

The associated conditions, enumerated in Section II., may be as important as the actual climatic changes, if, indeed, they are not more so—that is, the climatic effect is often indirect.

Which of these shall be investigated in its relation to climatic and disease variation, and how far this investigation shall be carried, are matters which the individual observer must decide for himself. But usually material relating to most of these points is already available, many of which are of economic importance, and so have received early attention; this in many cases will be sufficient Every investigation has a natural tendency to expansion; this can never be entirely obviated; points crop up which need special inquiry. But a careful consideration at the outset of the possible lines of expansion will often enable the observer to obtain contemporaneous records which may prove useful, which he could possibly never obtain later or from other sources. A working hypothesis is helpful, provided that it is regarded as a scaffolding to disappear in the finished work, and it is not allowed to influence the selection of the observations. The difficulty at the outset is to distinguish between the essential and the adventitious; this becomes easier as the inquiry proceeds. But when the observer has no knowledge of what auxiliary material is available, it is better to observe those associated conditions which appear to be essential than to trust to the existence of records which may be deficient on this very point.

Of the associated conditions, probably those termed biological form at present the most promising field for investigation, especially as regards the incidence of many forms of tropical disease. Much work has been done in this direction, especially in regard to mosquitoes and ticks, but fuller investigations are still useful, especially the relation (direct or through vegetation changes) of climatic conditions to the life history of the carrier and the development of the parasite carried, and hence,

APPENDIX III

MONTHLY RETURN FROM NORMAL CLIMATOLOGICAL STATIONS

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APPENDIX IV

A.—TABLE GIVING A SUMMARY OF THE METEOROLOGICAL OBSERVATIONS MADE AT 8 A.M. AND 6 P.M., OR AT 9 A.M. AND 9 P.M. IN THE BRITISH ISLANDS DURING THE MONTH OF

The observations are made at certain set hours daily, but the Numbers of Days of Rain, Snow, Hail, Thunderstorm and Gale are counted irrespective of the Hours at which they occurred.

Mean at 32° F. at Station Level	Diff. from Av.	Mean of A Min.	Mean of B Max.	Mean of A and B	Diff. from Av.	Absolute Minimum and Maximum: Min.	Day	Max.	Day	Observations at 8 a.m. and 6 p.m., or at 9 a.m. and 9 p.m.: Dry Bulb a.m.	p.m.	Dew Point a.m.	p.m.	Vap. Pressure a.m.	p.m.	Humidity a.m.	p.m.	At 1 foot depth	At 4 feet depth	Total in Hours	Diff. from Av.	Per cent.	Diff. from Av.	Mean Amount	No. of Days	Total Fall	Diff. from Av.	Most in a day: Amount	Day	Snow	Hail

B.—TABLE. SUMMARY OF THE OBSERVATIONS OF TEMPERATURE, RAINFALL, AND BRIGHT SUNSHINE AT OTHER STATIONS.

District	Station	Air Temperature: Mean of A Min.	Mean of B Max.	Mean of A and B	Diff. of Mean from Av.	Absolute Min.	Day	Max.	Day	Rain and other Forms of Precipitation: Number of Days	Total Fall	Diff. from Av.	Most in a day: Amt.	Day	Bright Sunshine: Total in Hours	Diff. from Av.	Per cent.	Diff. from Av.

APPENDIX V.

Form No. 34 WEEKLY CLIMATOLOGICAL REPORT FROM

Observations made at m. *each day by* *during the week ending Saturday,* 190 .

	Temperature	Rainfall	Sunshine	Other observations, if any	Remarks
		In inches and decimals	Total duration for the day shown by [illegible] in [illegible] ors and tenths		As to prevalence of Thunderstorms, Lightning, Hail, unusually heavy hailstorms, Hoar frost, snow, etc.

APPENDIX VI.

MONTHLY RETURN OF DISEASES

Total population among whom the cases of sickness and the deaths occurred { *Male* ______ *Female* ______

Number	Name	Cases admitted	Died during	Males												Females											
				Under 1 year	1 and under 5	5 and under 10	10 and under 15	15 and under 20	20 and under 25	25 and under 35	35 and under 45	45 and under 55	55 and under 65	65 and under 75	75 and upwards	Under 1 year	1 and under 5	5 and under 10	10 and under 15	15 and under 20	20 and under 75	25 and under 15	35 and under 45	45 and under 55	55 and under 65	65 and under 75	75 and upwards

indirectly, their relation to the incidence of disease. The literature of the subject is already enormous, but much yet remains to be done.

Appended to this Memorandum are lists of Central Offices where meteorological publications are collected, and of Learned Societies and Institutions to which inquiries for special information may be addressed. There are, in addition to those enumerated (which are chiefly British), usually local societies in various foreign countries, from which much valuable information may be obtained. It is impossible to give a complete list of such societies, but observers will be given all the information that is available concerning them on application to the Central Committee.

R. J. S. SIMPSON.

List of Central Offices where Meteorological Publications are collected.

EUROPE.

AUSTRIA-HUNGARY:
Buda-Pest—K. Ungar. Meteorologische Centralanstalt.
Vienna—K.-K. Centralanstalt für Meteorologie.

BELGIUM:
Brussels—Observatoire Royal, Uccle.

BULGARIA:
Sofia—Station Centrale Météorologique.

DENMARK:
Copenhagen—Det Danske Meteorologiske Institut.

FRANCE:
Marseilles—Commission Météorologique.
Paris—Bureau Central Météorologique.

GERMANY:
Berlin—K. P. Meteorologisches Institut.
Carlsruhe—Central Bureau für Meteorologie und Hydrographie.
Dresden—K. S. Meteorologisches Institut.
Hamburg—Deutsche Seewarte.
Munich—K. B. Meteorologische Centralanstalt.
Strassburg—Meteorologischer Landesdienst.
Stuttgart—K. W. Meteorologische Centralstation.

GREECE:
Athens—Observatoire National.

HOLLAND:
Utrecht (de Bilt)—Koninkl. Nederl. Meteorol. Institut.

ITALY:
Rome—Ufficio Centrale Meteorologico e Geodinamico.

NORWAY:
Christiania—Det Norske Meteorologiske Institut.

PORTUGAL:
Lisbon—Observatoire Coimbra.
Azores—Observatoire Punta Delgada.

ROUMANIA:
Bucharest—Institut Meteorologicul.

RUSSIA:
St. Petersburg—Observatoire Physique Central

SERVIA:
Belgrade—Observatoire Central.

SPAIN:
Madrid—Instituto Central Meteorológico; Real Observatorio.

SWEDEN:
Stockholm—Meteorologiska Central Anstalten.

SWITZERLAND:
Berne—Bureau Hydrométrique Fédéral.
Zurich—Schweizerische Meteorologische Centralanstalt.

AFRICA.

Algiers—Service Météorologique.
Cairo—Survey Department.
Cape Town—Meteorological Commission; Observatory.
Durban—Natal Observatory.
Johannesburg—Transvaal Meteorological Department.

ASIA.

Bombay—Colaba Observatory.
Calcutta—Meteorological Office.
Hong Kong—Observatory.
Shanghai—The Observatory, Zi-ka-wei.
Simla—Meteorological Office.
Tokio—Imperial Meteorological Observatory.

INDIAN OCEAN.

Mauritius—Royal Alfred Observatory.

AMERICA.

Toronto—Meteorological Office.
Washington—Weather Bureau.
Argentina—Oficina Meteorológica, Córdoba.
Mexico—Observatorio Central Meteorológico.
Rio Janeiro—Observatorio.
Valparaiso—Servicios Meteorológico y Colombofilo.

AUSTRALASIA.

Adelaide—The Government Astronomer, Observatory Department.
Brisbane—The Government Meteorologist.
Melbourne—Observatory.
Sydney—Observatory.

List of Learned Societies and Institutions in the United Kingdom to which Inquiries for Special Information may be addressed.

GENERAL SCIENCE.

LONDON:
Royal Society, Burlington House, W.
Royal Institution of Great Britain, Albemarle Street, W.
Royal Asiatic Society, 22 Albemarle Street, W.
Imperial Institute, South Kensington, S.W.
African Society, 22 Albemarle Street, W.
London Institute, Finsbury Circus, E.C.

EDINBURGH:
Royal Society of Edinburgh, The Mound, Princes Street.
Royal Physical Society of Edinburgh, 1 India Buildings.

DUBLIN:
Royal Dublin Society, Leinster House, Dublin.
Royal Irish Academy, 19 Dawson Street.

PHYSICAL, &c.

LONDON:

Royal Astronomical Society, Burlington House, W.
British Astronomical Association, 85 Gracechurch Street, E.C.
Royal Meteorological Society, 70 Victoria Street, S.W.

EDINBURGH:

Scottish Meteorological Society, 122 George Street.

GEOGRAPHY, GEOLOGY, &c.

LONDON:

Royal Geographical Society, 1 Savile Row, W.
Geological Society of London, Burlington House, W.

EDINBURGH:

Edinburgh Geological Society, India Buildings.
Royal Scottish Geographical Society, Queen Street.

BIOLOGY, &c.

LONDON:

Linnean Society of London, Burlington House, W.
Anthropological Institute of Great Britain, 3 Hanover Square, W.
Natural History Museum, Cromwell Road, S.W.
Zoological Society of London, 3 Hanover Square, W.
Royal Botanic Society, Regent's Park.
Entomological Society of London, 11 Chandos Street, W.

ECONOMIC SCIENCE AND STATISTICS.

LONDON:

Royal Statistical Society, 9 Adelphi Terrace, W.C.

DUBLIN:

Statistical and Social Inquiry Society, 35 Molesworth Street.

AGRICULTURE AND HORTICULTURE.

LONDON:

Royal Agricultural Society of England, 13 Hanover Square, W.
Royal Horticultural Society, Vincent Square, S.W.

MEDICINE AND PUBLIC HEALTH.

LONDON:

Local Government Board, Whitehall, S.W.
Medical Society of London, 11 Chandos Street, W.
Royal Society of Medicine, 20 Hanover Square, W.
British Balneological and Climatological Society, 20 Hanover Square, W.
Dermatological Society of London, 11 Chandos Street, W.
Epidemiological Society of London, 11 Chandos Street, W.
Incorporated Society of Medical Officers of Health, 1 Upper Montague Street, W.C.
Medico-Psychological Association of Great Britain and Ireland, 11 Chandos Street, W.
Neurological Society of the United Kingdom, 11 Chandos Street, W.
Pathological Society of London, 20 Hanover Square, W.
Royal Institute of Public Health, Russell Square, W.C.
Royal Sanitary Institute, Parkes Museum, Margaret Street, W.
National Association for the Prevention of Consumption, 20 Hanover Sq., W.
Surveyors' Institution, 12 Great George Street, S.W.

EDINBURGH:

Edinburgh Health Society, 43 Queen Street.
Edinburgh Medico-Chirurgical Society, 117 George Street.

GLASGOW:

Incorporated Sanitary Association of Scotland, 83 Bath Street.

DUBLIN:

Dublin Sanitary Association, 42 Dame Street.

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, Miss A. J. COOPER, *and* Dr. ETHEL WILLIAMS.

THE Committee had in co-operation with them in their investigations and deliberations the valuable assistance of Dr. C. Childs, Dr. James Kerr, Professor W. N. Shaw, Dr. C. E. Shelley, Mr. J. Osborne Smith, and Mrs. White Wallis.

Several matters concerning the health of children in schools have been referred to sub-committees, but owing to a misunderstanding as to the reappointment of the Committee there has not been time to report. They have, however, adopted and submit to the Association a final report prepared by a sub-committee with regard to the ventilation of schools.

The Ventilation of School Buildings.

General Considerations.—Ventilation implies the continuous adequate supply of pure air to all parts of inhabited buildings and the removal therefrom of fouled air without causing inconvenience or ill-health to the occupants.

In order to ensure this it is necessary to consider :—

1. The supply of sufficient quantity.
2. The proper quality of the air supplied.
3. The suitable degree of temperature and humidity—
   (*a*) Of the air as supplied.
   (*b*) Of the air in the room (or other enclosed space) during occupation.
4. The distribution in equal proportion to each occupant.
5. The complete removal of fouled air.
6. The provision of such ventilation—
   (*a*) Without producing discomfort or feeling of draught, or any gradual though imperceptible depression of health.
   (*b*) In such a way as to maintain full bodily and mental vigour.
   (*c*) In such a way that the whole process shall be reasonably practicable and economical.

Without a knowledge of the above requirements and a practical knowledge of the complicated physical problems involved in ventilation it is impossible to devise a rational and efficient scheme of ventilation, or to form a reliable judgment upon any schemes of ventilation which may be under consideration.

The Amount of Air required for Efficient Ventilation.

The problem of the satisfactory ventilation of rooms intended for the accommodation of a considerable number of persons must be regarded as being still in the experimental stage, and therefore no categorical statement can be given as to the amount of air required to secure the object in view. The Committee accordingly confine themselves to recommending that the allowance of air for each person should not be less than 2,000 cubic feet per hour, and to giving an indication of the reasons which lead them to this recommendation.

They regard as ideal ventilation the condition of things which would be given by general perflation on a day when the natural temperature of the air is 62° or 63° F. In practice the air supplied must be confined if it is to be warmed; cold walls and windows also disturb the simplicity of the arrangement.

The Committee have no evidence to show what amount of air would be supplied under the conditions of ideal ventilation above mentioned; it would probably be far larger than the amount supplied by ventilating systems in practical use, and the estimates of the quantity of air required are based upon other considerations.

The most common basis of calculation starts from de Chaumont's estimate of the amount necessary to prevent any disagreeable smell or feeling of closeness being perceived by a person coming from the outside air directly into the room. This, again, has been interpreted by various authorities in terms of the excess of carbonic acid in the air of the room over that in the outside air. In taking samples of air for analysis regard must be paid to the proportion of carbonic acid possibly being varied in different parts of the room, and as far as possible the average proportion should be ascertained. Different authorities fix the limit of 'respiratory impurity' from this point of view as that indicated by 2 per 10,000 (which corresponds to a supply of about 3,000 cubic feet of air per hour for adults and somewhat less for children during continuous occupation) to 6 per 10,000 (for which a supply of 1,000 cubic feet of air per hour would be sufficient).

Bacteriological tests of air have been made, but no quantitative statements as to the amount of air required have been based upon the results.

Another basis of computation is the amount of air necessary to remove the 'heat of combustion' of the persons in the room. It has been calculated that this heat is sufficient in an adult to raise the temperature of 3,000 cubic feet of air per hour by 5° F.; and, generally speaking, it is by the warming of the air through omission of heat from their bodies that the individuals in an occupied room dispose of their waste products and supply themselves with their share of the fresh air which is delivered to the room. It is clear that it is desirable to remove this heat by removing the air which has been fouled. To remove the heat by conduction through walls and windows while retaining the impurities is not a satisfactory means of maintaining a suitable average temperature, and it should be avoided as far as possible. Restricting the air-supply implies a correspondingly greater increase of its temperature by the occupants themselves during its passage through the room, and is on that account objectionable; and for the same mean or final temperature it implies a proportionately colder supply and consequently more appreciable draughts. Thus 1,000 cubic feet would be warmed 15° per hour by an occupant, and to keep air in a room until it has been warmed 15° F. by the occupants would at least produce discomfort. The 1,000 cubic feet per hour supply must on this account be regarded as too small. It will probably be allowed, for example, that if air were supplied to a room at 63° F. everyone would wish it removed before it had been raised to 70° F. by the inmates themselves. Upon this basis of calculation here put forward 2,000 cubic feet per hour must be supplied to each inmate for that purpose. There would be no advantage from the point of view of freshness in having it merely cooled by walls or windows; and hence, without laying too much stress on the precision of the numeral calculations, a supply less than 2,000 must be regarded as inadequate.

A third consideration is the removal of the solid and liquid particles which find their way into the air from the skin or clothing, or from the mouth, or by raising the dust from the floor and surfaces of seats, desks, &c. These particles, which often carry organisms, pathogenic or otherwise, may be regarded from the physical point of view as fine dust which is constantly in process of settling, but so slowly that the greater part of it takes part even in the slow circulation of the air in an inhabited room. It can hardly be denied that these particles when associated with or derived from infectious sources may form the most injurious constituents of a vitiated atmosphere. We know little of their size or nature, but their behaviour in the air must be represented more or less aptly by that of the cloud of particles which constitutes tobacco smoke, and we may judge from the behaviour of such a cloud what is the best course to pursue in order to remove the obnoxious particles. On this analogy it is clear that the less vigorous the circulation of air through the room the more the particles hang about the room, and we have thus another reason for maintaining the flow of air at the highest figure compatible with the comfort of the occupants.

Von Pettenkofer's method of estimating the quantity of air required by considering the dilution of carbonic acid draws a distinction between adults and children. The considerations which have been adduced tend to show that the introduction of any such distinction in practical ventilation would indicate a degree of accuracy in our knowledge of the processes of ventilation to which we can lay no claim. Even if it be true that the production of carbonic acid increases with the body weight, it is not a necessary consequence that the natural demand for fresh air increases in the same proportion, and we are not prepared to say that a boy or girl should be supplied with less air than a man or woman.

We may sum the considerations by saying that a supply of 1,000 cubic feet per head per hour to healthy occupants will barely save the room from becoming disagreeable. A supply of 2,000 cubic feet is the smallest that can be recommended for health, mental energy, and comfort. More still would be required in order to approach the conditions of ideal ventilation.

The Suitable Degree of Temperature and Humidity.

Recent investigations, more especially those of Haldane and others in this country, of Flügge and Paul in Germany, have shown that the temperature of a room and of the air supplied is of greater importance than has generally been supposed; that a high degree of temperature in a room (*e.g.*, above 68° F.) produces languor, sense of mental fatigue, and the other symptoms associated with crowded assemblies, to a greater extent even than polluted air; and that these symptoms are aggravated by stagnation and immediately relieved by movement of the air surrounding the body.

These results have been confirmed by the careful observations suggested by the work of this Committee and recently carried out in the London schools.

From the same observations it has been shown that a high degree of humidity of the air does not interfere with the comfort and mental energy of the scholars in a room provided that the temperature is not above 65° F. Above that temperature it produces marked decrease of mental energy.

The temperature most conducive to comfort and mental vigour in a schoolroom is between 58° and 62°, irrespective of the degree of humidity.

Furthur investigation is required in order to determine the maximum temperature of the air which may be introduced into a room without producing physiological disturbance. It would be probably safe to state that in no case should the temperature of the warmed air so introduced exceed by more than one degree the proposed normal temperature of the room.

If a room supplied with warmed air becomes too cold, owing to loss of heat through walls and windows, it should be further warmed by some form of radiant heat.

The Distribution in equal Proportion to each Occupant.

It is generally assumed that in a mechanically ventilated room the air is thoroughly mixed, so that the fresh air supplied is distributed in equal proportion to each occupant. Further observations are required in this respect, and also upon the best methods for securing this equal distribution, the best position, size, and shape of inlet shafts, the relative sizes and positions of inlets and outlets.

In many schoolrooms ventilated mechanically inlets and outlets are so arranged that shortcircuiting of the air-supply is inevitable, and occasionally stagnant spaces are to be found.

In 'naturally' ventilated rooms the fresh air supplied during cold weather inevitably gravitates to the floor unless it be warmed before admission, forming a cold floor-current which chills the feet and lower extremities of the occupants without materially contributing to the ventilation.

The heat evolved from the body of each individual undoubtedly causes a local upward current of air, and induces a fresh supply of air to each body. The force of this upward current and its value so far as it supplies fresh air to the individual require further investigation. It probably contributes considerably to the special supply for each occupant of the room.

Ventilation as a Measure for reducing Risks of Infection.

By far the most important measure for the prevention of infection when a scholar has contracted infectious disease is the prompt detection and exclusion or removal of the infected individual.

Another important measure is the regular and effective cleansing of the floor, walls, ceiling, furniture, &c., in the room by means of damp cloths in such a way as to remove the dust and the bacteria contained in it without allowing them to be merely displaced and scattered about in the air of the room. Efficient ventilation, however, can to some extent be made to help in reducing the risks of infection by removing the majority of microbes present in the air.

In the investigations of Carnelly and Haldane in 1886–89 it was shown that mechanical ventilation removed most of the microbes contributed from the bodies and clothing of the occupants.

These observations indicated that in mechanical ventilation a steady movement of the air was maintained throughout the room, tending to prevent the microbes from settling on surfaces and to convey them out of the room.

It is desirable that similar investigations should be carried out with the aid of the more complete methods of bacteriological investigation now at our command.

Comparison of Mechanical and Natural Ventilation.

On comparing together mechanical and natural ventilation it is seen that they each have their advantages and disadvantages. By means of mechanical ventilation the air-supply can be better controlled, washed and filtered from dust, heated or cooled; the disturbing influence of variation in the force and direction of wind can be more easily overcome; the required temperature of the room more steadily maintained.

On the other hand, mechanical ventilation is far more costly: the process is placed almost entirely in the hands of one individual, generally remote from the schoolroom, whilst at the same time both teachers and scholars are deprived of the salutary object-lesson afforded by 'natural ventilation' in the desirability of admitting fresh air into all occupied rooms and dwellings.

Recommendations.

From the foregoing statements it will be seen that the Committee are of opinion that a large number of investigations will have to be made before a final opinion can be formed with regard to many points in connection with the problems involved in practical ventilation; for instance, the position and size of inlets and outlets, the best means for the impartial distribution of the fresh air supplied, the relative advantages of mechanical as compared with 'natural ventilation,' the best mode of conveying heat.

Until such final opinion is formed, the best systems of ventilation will suffer discredit owing to faulty and defective methods of carrying them out; great expenses may be needlessly incurred in the construction of ventilation installations, whilst those who are responsible for the management of schools will be constantly harassed by new regulations and uncalled-for expenditure without obtaining any real improvement in the ventilation.

The Committee have endeavoured to make investigations on some of the points mentioned above, but have not the means or authority for carrying them out. They suggest that inquirers well versed in the scientific aspect of the question, and acquainted with the practical methods employed for ventilation, as well as with the requirements and practical business management of schools, should be commissioned to carry out such investigations; that schoolrooms, some provided with mechanical, others with 'natural' systems of ventilation, be put at their disposal for this purpose; that the time is ripe for a carefully conducted investigation on scientific lines of the whole subject of school ventilation.

After consideration of the important conclusions arrived at in this report the Committee urge the British Association to move for the appointment of a Royal Commission or departmental committee with the necessary authority fully to investigate the subject.

The Committee desire to be reappointed, and ask for a grant of 10*l.* for the purpose of obtaining instruments for investigation in hearing tests for school use.

The Electrical Phenomena and Metabolism of Arum spadices.—*Report of the Committee, consisting of* Professor A. D. WALLER (*Chairman*), Miss SANDERS (*Secretary*), Professor GOTCH, *and* Professor FARMER.

Report of Dr. A. D. WALLER, F.R.S., *on the work of* Miss SANDERS *and* Miss KEMP *during the year* 1907–08.

THE work during the past year upon *Arum spadices* by Miss Sanders and Miss Kemp, although it has not been very fruitful as regards the original object of the inquiry, has given rise to observations and experiments which are in my opinion of very considerable value, and promise to lead to further results of positive importance in vegetable and in animal physiology.

The actual results as regards the *Arum spadices* are described in the report of Miss Sanders; that of Miss Kemp deals with the general question of the transmission of stimuli in vegetable tissues, which was the first outcome of the original inquiry. This question has been touched upon by many previous observers by more or less definite methods and with more or less definite conclusions. I have myself for many years had this problem before my mind, and I am glad to take this opportunity of stating my attitude towards it (*vide infra*).

The observations of Miss Kemp have, however, not been limited to this single problem. In consequence of the manner in which it has been treated in the recent publications of Professor J. C. Bose, Miss Kemp was led to examine some of the data upon which that author has rested his claim to have discovered the existence of vegetable nerves. As presented by him these data consist essentially in the statement that a close parallelism exists between the contractions of fibro-vascular bundles in vegetables and those of ordinary nerves in animals. The results of Miss Kemp's experiments with me are given in a joint paper to the Physiological Society,[1] entitled 'A Demonstration of the "Contractility" of Nerve, of Fiddle-strings, and of other Strings,' to indicate the illusory nature of Professor Bose's results, which, according to our experiments, are entirely due to the heating effects of the high-tension induction currents used for stimulation.

The consideration of the effects of heat naturally led to a consideration of the question whether or no heat *per se* may properly be regarded as a physiological stimulus of vegetable or animal protoplasm. Obviously temperature is a condition of stimulation, but the question to which we

[1] *Proceedings Physiol. Soc. Journal of Physiology*, 1908, vol. xxxvii.

addressed ourselves was whether the sudden application of heat—a thermic shock, so to speak—could act as a true stimulus in the sense that an electric shock acts as a stimulus. Our results in this connection are not yet published; I may, however, so far anticipate them by stating—

(1) That as regards animal nerves the experimental answer is clearly negative.

(2) That as regards vegetable tissues the answer is in all probability negative, the effects of thermic shocks being, in my opinion, due to movements of water rather than to excited and transmitted protoplasmic activity.

(3) That the above two considerations lead to the reinvestigation of Hermann's fundamental principle to the effect that warmer tissue is galvanometrically positive to cooler tissue.[1]

This third point will, I hope, form the subject-matter of an early communication to the Physiological Society. At present I am not sure of the fact as stated by Hermann, nor therefore obviously of its possible interpretation, as to whether it be due to unequal ionic velocities of dissociating molecules or to mere water movements from or towards the heated spot.

The problem of transmission in vegetable protoplasm in the definite restricted sense of the propagation of an excited state from cell to cell has been previously approached by several observers and theorists.

The principal authors to whom I have referred have been Burdon Sanderson, Haberlandt, Nemec, and Bose.

My first definite knowledge[2] of the question of transmission of the excitatory state in plant protoplasm was derived from the papers of Burdon Sanderson on *Dionæa*. In the course of the observations by which he sought to establish a comparison between vegetable and animal tissues as regards their mechanical and electrical responses to excitation, he showed that, in consequence of mechanical or electrical excitation of a hairlet, an electrical response of an opposite lobe of the leaf of *Dionæa* took place, thus clearly proving that in the case of a sensitive plant transmission of excitation does actually occur. In fig. 10, p. 21,[3] a diagram of what he terms the fundamental experiment is given in which an electrical response of one lobe is observed consequent upon an electrical excitation applied to the other lobe. With some reservation (p. 40) he gives as the probable rate of transmission 'at least 200 mm. per second.' In his second paper[4] Burdon Sanderson (pp. 444, 445) gives the rate as 200 to 300 mm. per second, according to temperature, and explicitly concludes that 'the excitatory process in the leaf is of the same nature as that which follows stimulation in animal structures, and more particularly in nerve.' And the beautiful electrometer records given in illustration of this paper exhibit diphasic effects in *Dionæa* essentially

[1] Pflüger's *Archiv*, vol. iv. 1871, p. 163.

[2] Through the writings of Claude Bernard, and his description of the action of anæsthetics on *Mimosa*, my attention had been directed to the previous observations of Dutrochet (1824), who first measured the speed of propagation in *Mimosa*, and gave it as being 2 to 3 mm. per second. Paul Bert (1870) gave it as being 2 to 5 mm. per second.

[3] *Phil. Trans.*, 1881, 'On the Electromotive Properties of the Leaf of *Dionæa* in the excited and unexcited states.'

[4] *Ibid.*, 1888.

similar to diphasic effects on nerve and muscle. The only difference is one of speed, viz.—

M. 0·300 in *Dionæa*.
3·000 in ordinary muscle.
0·150 in cardiac muscle.
30·000 in nerve.

The transmission in *Biophytum* was studied and described in 1890 and in 1898 by Haberlandt in the Buitenzorg Laboratory (Ueber die Reizbewegung und die Reizfortpflanzung bei *Biophytum sensitivum*, 'Annales du jardin botanique de Buitenzorg,' Suppl. ii., 1898, p. 33). Haberland gave as the speed of transmission at its quickest 2·5 to 3 mm. per second, as compared with 8 mm. per second in *Mimosa*.

In a more recent publication ('Sinnesorgane im Pflanzenreich,' Leipzig, 1901), Haberlandt (p. 152) compares transmission in plants with the cell-to-cell transmission obtaining in cardiac muscle, and rejects the assumption of special fibrillar paths of excitation in vegetable tissues.

Bose ('Comparative Electro-physiology,' 1907, chap. xxx.) deals with the subject of transmission in plants at considerable length. He gives, *e.g.*, as having been determined by himself by the electromotive method, the following values: *Mimosa* petiole, 14 mm. per second; isolated nerve of fern, 50 mm. per second; and is of opinion (p. 453) that, since the conduction of 'excitation takes place by the transmission of protoplasmic changes, it is evident that it must occur most easily along those paths in which there is greatest protoplasmic continuity. It is clear that certain elements in the fibro-vascular bundles will furnish the best conducting medium.'

But the data upon which the author rests his opinion do not bear examination; in fact, the chapter on the matter contains no data unless the diagram on p. 454 of an experimental arrangement for comparing transverse and longitudinal conductivities be regarded as a datum. Moreover, as stated above, the discovery of vegetal nerves similar to animal nerves is altogether illusory.

Report of Miss SANDERS' *Work done on Metabolism of* Arum spadices, 1908 (January to July).

The subject proper of the present inquiry—viz., the further elucidation of the changes going on in *Arum spadices* during inflorescence—has been but little advanced this year owing to the difficulty of bringing plants during their first season to a proper state of inflorescence.

The points which we held before us particularly were :—

1. The normal electrical conditions of variously active phases.
2. The chemical products of the proteolytic activity which had been shown to exist.

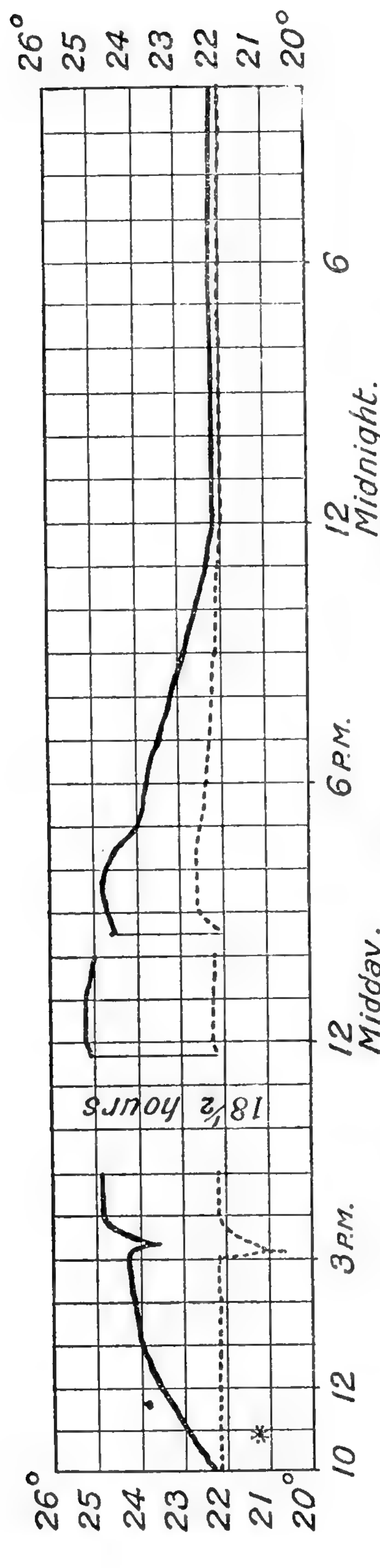
2*b*. The relation between the secretion of oxidases and amylases.

3. The behaviour of the active parts under traumatic conditions and after stimulation.

These points we desire to keep in view for a possible larger supply of flowers in the future.

From the few plants (about fifty) that flowered properly this season it was, however, found possible to extend observations on (*a*) the enzyme activity; (*b*) the nuclear changes of cells governing this intense metabolism. Of these I hope to give figures in September.

1908.



* marks opening of spathe and protrusion of stigmatic hairs.

FIG. 1.—Temperatures at anther-whorl and spadix tip of *Dracunculus vulgaris* during the entire phase from opening (protrusion of stigmatic hairs) to fading of the spadix.

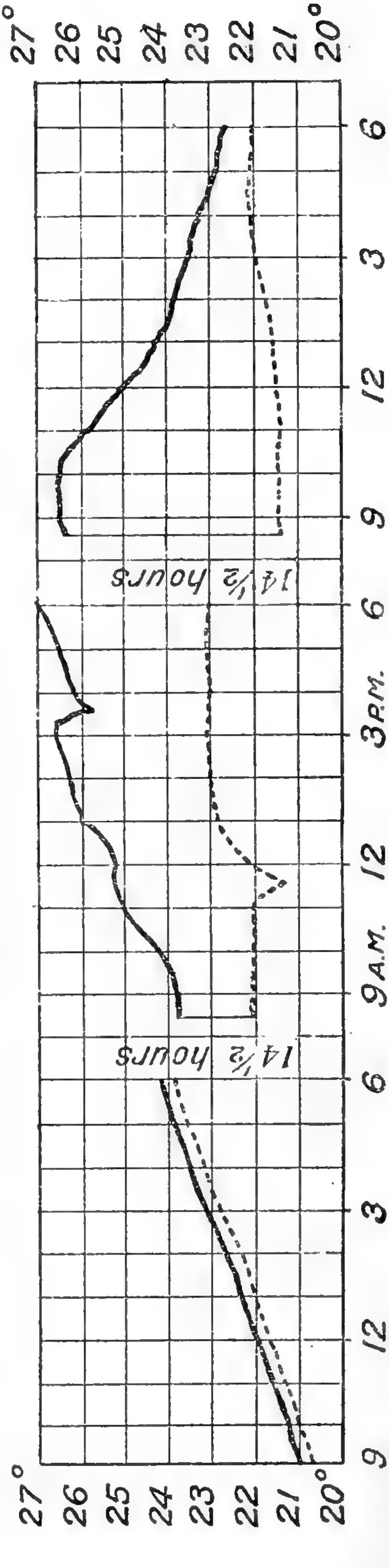


FIG. 2.—A second plant. Observations of the same regions.

Coincidently with some electrical experiments (not sufficiently repeated for any definite result), Miss Kemp took observations of the temperature changes in *Dracunculus vulgaris* at a more active and less active portion of the spadix. The accompanying figures show the course of these changes in two typical cases. Miss Kemp has succeeded in locating the region of greatest heat rise to the anther-whorls and the short starchy portion, beset with club-shaped guards, immediately below. The region of the ovules is not involved, as I had previously imagined.

The plotted curves which I gave in my first communication to show the relation between rise of temperature and evolution of CO_2 may conveniently be shown for comparison with those of *D. vulgaris.*

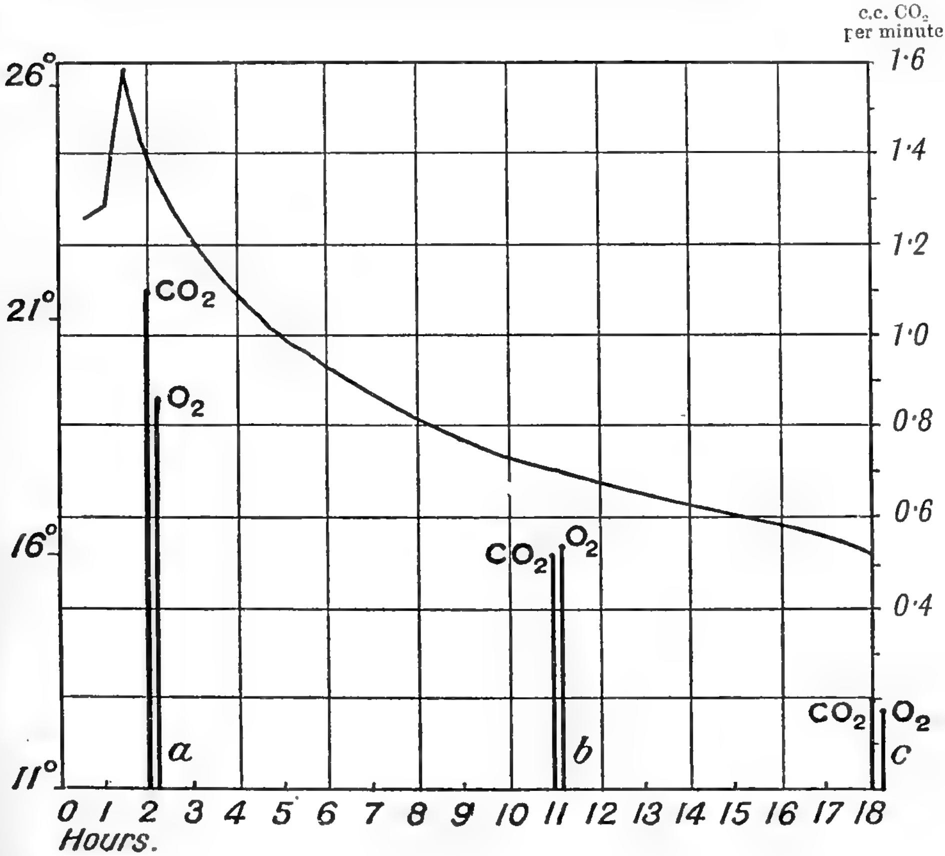


FIG. 3.

Temperature curve of the spadix of *Arum italicum* from protrusion of stigmatic hairs to commencement of fading. The vertical lines at *a*, *b*, *c* indicate the CO_2 production and O_2 absorption in cubic centimetres per minute. The change is more rapid and greater in species like the present, where the rise of temperature occurs in the spadix than it is in *Dracunculus*, where the starchy contents of the spadix are much reduced, and the seat of change is the anther-whorl.

(*a*) *Enzyme Activity.*—As before stated, it has been impossible to take any chemical analyses owing to the lack of material. Miss M. T. Fraser, B.Sc., most kindly undertook this part of the inquiry. Her detailed report waits, as experiments are still going on. She began by repeating Miss Kemp's work of last year with slightly different conditions ;

the former results stand confirmed and some new points established, so that we may sum up our present knowledge as follows: The

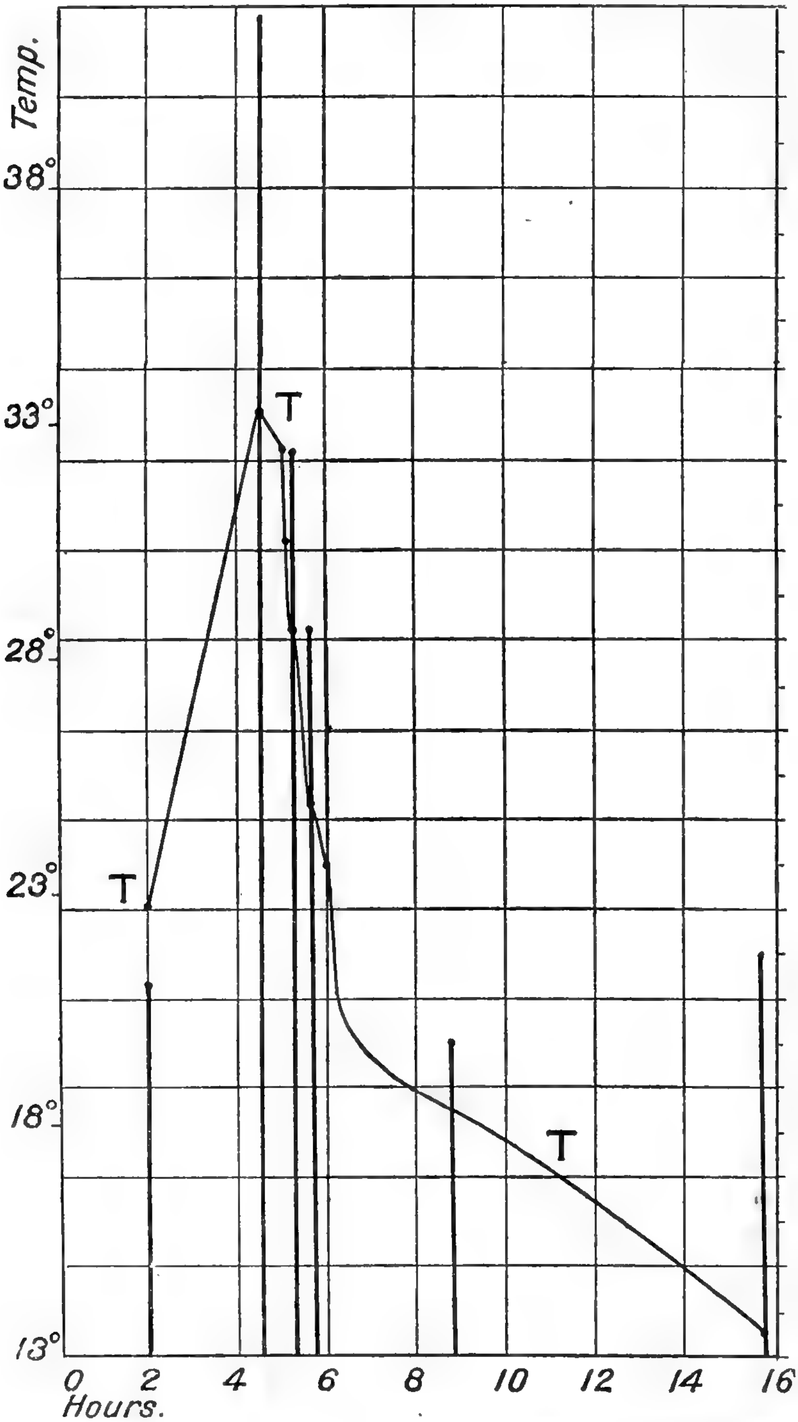


FIG. 4.—Temperature curve T T T of *Arum maculatum*. The vertical bars indicate CO_2 production in cubic centimetres per minute.

active spadices of *A. italicum*, *A. crinoides*, *A. crinitum*, and *D. vulgaris* secrete a proteolytic enzyme or enzymes readily extracted in water, comparable with trypsin in attacking proteids and peptones, but carrying the process of splitting to a further stage in which tryptophane can no longer be detected.

The proteids used were: The tissues of the plant itself (H. P. K. and M. T. F.); Vermicelli (M. T. F.); Fibrin (H. P. K. and M. T. E.); Barley (H. P. K.).

The enzymes will not attach themselves to the solid proteid particles, but remain in the solution (fibrin standing for some hours in spadix extract and then washed remains unattacked.—H. P. K. and M. T. F.). The use of a bottle-shaker, therefore, greatly accelerates the action.

Miss Fraser has succeeded in showing the complete destruction of tryptophane (in a pancreas digest) by the addition of spadix enzyme, the boiled control giving at the same time a strong tryptophane reaction. This point, which seemed so probable last year, it was chiefly desired to establish.

Miss Fraser is still experimenting as to the splitting of *sugars* by the plant enzymes. It may be remembered that the splitting of starch was shown by all species investigated; but the fact that we could not ascertain which sugars resulted by any of the ordinary methods has suggested this possible further stage on the carbohydrate side parallel to the complete breaking down of the proteids.

(*b*) *Nuclear Conditions.*—The first point which attracted me to the investigation of the aroid inflorescence was the idea that they would probably show nuclear changes governing enzyme secretion similar to those which Miss Huie found to exist in *Drosera.* I have fixed material in some of the media advocated by Dr. Gustav Mann at different stages: bud, hot-phase, fading-flower.

Paraffin sections stained by Mann's methyl-blue-eosin method, or in hæmatozylin-eosin, display a short mitotic phase (from generally distributed chromatin to chromosomes) accompanied by an inversion of ionic conditions in *A. dracunculus.*

Notes by Miss Fraser, *B.Sc.*

I. *Auto-digestion.*—Extract of spadix of *Arum dracunculus* shows tryptophane, which disappears after twelve hours—boiled control negative.

Extract of spadix of *Arum italicum* gives starch disappearance in twelve hours in unboiled solution after several days in boiled control.

Tryptophane never appears in extracts of stem and leaves.

II. *Mixtures of Extracts of Spadices with various Substrates.*—Extract of spadix of *Arum crinitum* with tryptophane solution gives disappearance of tryptophane after four days in unboiled solution. Tryptophame still present in boiled after fourteen days.

Spadix of *Arum dioscoridis spectabile* after ten days gives disappearance of tryptophane in unboiled extract.

Extract of spadix of *Arum dioscoridis spectabile* with vermicelli gives tryptophane after a week—boiled control negative.

Extract of spadix of *Arum dracunculus* with Witte's peptone gives tryptophane after a week—boiled control negative.

Extract of spadix of *Arum dracunculus* with fibrin gives tryptophane after ten days.

Extracts with casein, gelatine, give negative results. Extracts of spadices of *Aurum crinitum, dracunculus, dioscoridis spectabile* give no disappearance of sugar after ten days in solutions of dextrose and maltose (5, 3, 2, and 0·5 per cent.), but those experiments are still in progress.

III. *Decomposition Products.*—Quantity of material insufficient to isolate satisfactorily any products of decomposition in malodorous spadices, but merely empirical tests do not indicate the presence of indol and skatol. In the extract of mature spadix of *Arum crinitum* trimethylamine seems to be present, but the material was too scanty for isolation.

N.B.—Chloroform was found to be quite useless as an antiseptic where the experiments extended over many days.

Report of Miss Kemp *on the Occurrence in certain Vegetable Tissues of a Propagated Electrical Response to Stimulation.*

The literature dealing with the question of conduction of stimuli in plants has been admirably reviewed by Fitting,[1] who also gives a complete bibliography.

Fitting is of opinion that propagation of an excitatory change in response to a local stimulus occurs widely in plants and essentially in cells with living contents, though whether such propagation takes place by water movement on variations in the permeability of the cell membranes and osmotic pressure, by changes of the gaseous pressure, or by a more active metabolism of the individual cells remains problematic. He divides the tissues through which transmission may occur into two groups: (*a*) the living cells of the vascular bundles through which excitation may be transmitted, even when the tissue is under the influence of anæsthetic drugs or excessive changes of temperature; (*b*) the 'ground-tissue,' in which transmission is very dependent upon the condition of the plant. He states that the propagated activity is associated with galvanometric negativity, and gives as its speed in *Biophytum* 10–20 mm. per second.

The following observations have been carried out upon seedling plants of mustard, pea, bean, and further upon adult petioles of maidenhair fern. Electromotive variations have been taken as an index of the excitatory changes occurring within the tissue, the latter being led off by non-polarisable electrodes to a high-resistance galvanometer.

By using a double galvanometer circuit, with one instrument under observation in the laboratory and the other in a neighbouring photographic room, it was possible to record the variations obtained at the same time diagrammatically and photographically. I have made upwards of 120 plotted observations and photographs, of which eleven have been selected for representing the results in the present preliminary communication.

With the exception of a few cases where the nature of the stimulus was mechanical the thermo-electric method of stimulation has been used. By this method, in which a platinum wire previously fixed in position close to or actually against the tissue is heated by closure of an electric current, the objection of shifting contacts liable to occur with any mechanical form of stimulation is obviated. In each case the plant under observation was placed upon non-polarisable leading-off electrodes with an intrapolar distance of about $1\frac{1}{2}$ cm., and the stimulation was applied at points successively nearer to these electrodes. Under these conditions responses of an apparently diphasic character have been obtained at distances varying between 1–12 cm. from the point of stimulation.

The resulting curves appear to afford evidence of the propagation

[1] *Ergebnisse der Physiologie*, vol. v. p. 155.

through the tissue of a wave of excitation initiated at the point of stimulation and sweeping successively over the proximal and distal leading-off electrodes.

Plates I., IV., XI. give typical records obtained with mustard, pea, and maidenhair.

In the experiment with a mustard seedling shown in Plate I. three successive thermal stimuli were applied, at ten-minute intervals, to a spot 3 cm. distant from the proximal leading-off electrode B. They elicited three diphasic responses, of which the first and second are shown in Plate I. A fourth stimulus was almost and a fifth quite ineffectual; but on moving the exciting wire to a distance of 10 mm. from B an explosive double response was obtained on heating, followed by complete inertia (Plate I*a*, not shown). The interpolar distance of the leading-off electrodes was about 1 cm. The maximum value of the response was 7/100 volt.

Plate IV. (pea seedling) shows two successive responses, of which the second is monophasic of more than 5/100 voltage, at 1 cm., 2·5 cm. distance respectively.

The value of 1/100 volt is augmented by about 35 per cent. at the end of the experiment, showing that the electrical conductivity of the tissue is increased.

Plates XI. and XI*a* show the curves obtained with an adult maidenhair petiole.

In this experiment the first stimulation was given at a distance of 12 cm. from the proximal electrode B, and caused a double diphasic response, the first phase of which was rapid, the second prolonged and of rather more than 1/100 voltage. There was an apparent latency of response of about 30 seconds.

Second and third stimuli at 6 cm. and 3 cm. elicited multiple responses of considerable voltage.

At the end of the experiment the electrical conductivity of the tissue was found to be increased by more than 100 per cent.

Plates VIII. and IX. show an experiment with a broad bean seedling in which a mechanical stimulus—*i.e.*, the squeezing down of the stimulating wire on the tissue, so causing a slight flexion—proved considerably more effective than the thermal. The first diphasic effect (value over 2/100 volt) was in response to pressure at 8 cm. distance. Heating at this point caused only a slight response in the anomalous direction. The second monophasic effect resulted from pressure at 4 cm. distance and showed a latency of about 20 seconds.

The interpretation of these diphasic electromotive changes as indicative of an actual wave of excitation passing along the tissue is borne out by the fact that the second phase of the response—*i.e.*, that of negativity at the distal electrode A—may be obliterated by previously injuring the tissue at that spot. Such injury may be produced either by strong tetanisation or by a section.

Plate II. records an experiment with mustard in which after distal injury by section repeated monophasic deflections, indicative of galvanometric negativity of the uninjured spot, were obtained in response to thermic stimulation.

The transmission of electrical change may also be blocked by tetanising a portion of the tissue intermediate between the leading-off electrodes and the point of thermal stimulation. Although the electrical conductivity of the tetanised portion is increased by about tenfold, repeated stimuli on the further side of it produce no electromotive variation at the leading-off electrodes, but become immediately effectual on their application between the latter and the tetanised tissue.

That the excitatory change undergoes a considerable decrement during its transmission is suggested by the facts that a stimulus of given intensity and duration, ineffectual at a certain distance, may be effectual if that distance is diminished; that a stimulus repeated at points successively nearer to the leading-off electrodes elicits from a tissue in optimum condition responses of successively higher voltage; finally, that a first diphasic effect may on repetition of the stimulus at the same or a nearer point be followed, perhaps owing to fatigue of the tissue, by a simple monophasic response, showing that the wave has not in this case reached the distal electrode.

The present data are insufficient to determine the true nature of the change, by transmission of which an electrical disturbance is set up at points distant from that of the exciting stimulus. The question arises as to whether it is physiological in nature or a purely physical process independent of any activity of the living tissue as such. From the succulent nature of the seedlings used in the greater number of the experiments, as also from the fact that a thermal stimulus is almost invariably effective where a mechanical stimulus generally fails to elicit a response, it appears likely that the electrical variations observed may be due to a movement of water through the tissue set up by the sudden change of temperature. On the other hand, the remarkable response obtained from the maidenhair petiole, which is a particularly dry and juiceless tissue, can hardly be so explained. Again, that the transmission is essentially a physiological process appears from the following considerations:—

First, that in character and extent the propagation varies in accordance with the general character of the tissue tested. In a comparison of roots and shoots in the pea seedling a correspondence was found of general sluggishness of response with limited propagation in the root as compared with general excitability and extensive propagation in the shoot.

Again, that a very slight etiolation or unhealthiness of a plant destroys its power of propagating a stimulus, as seen with seedlings grown in the laboratory—*i.e.*, under bad conditions of nourishment and light—with these tissues, the results obtained, though at first good, were after continued growth consistently negative.

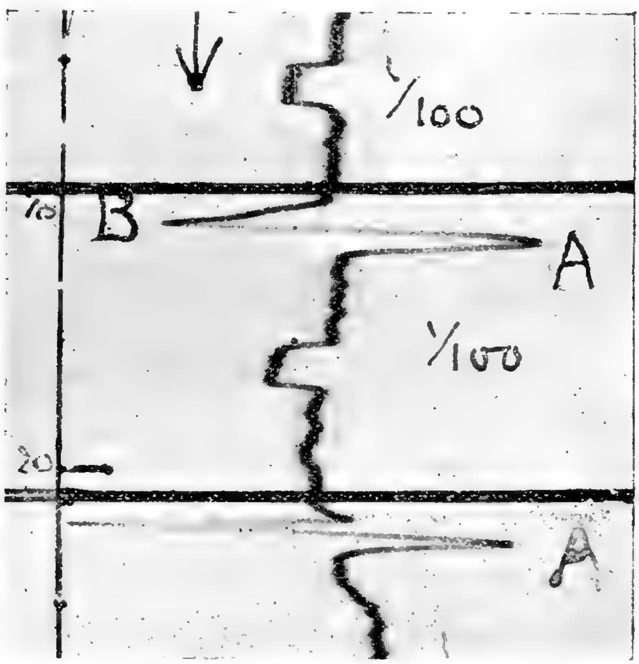
Again, that the tissue quickly fatigues unless in optimum condition, as appears from the fact, noted above, that a first diaphasic may be followed by a monophasic response, or in many cases by complete inexcitability.

Finally, that on altering the state of the tissue in such a way as to annul its power of response while at the same time greatly increasing its electrical conductivity—*e.g.*, by boiling or tetanising. No propagation of an excitatory state can be obtained with strong and repeated stimuli. Plate III. records such an experiment.

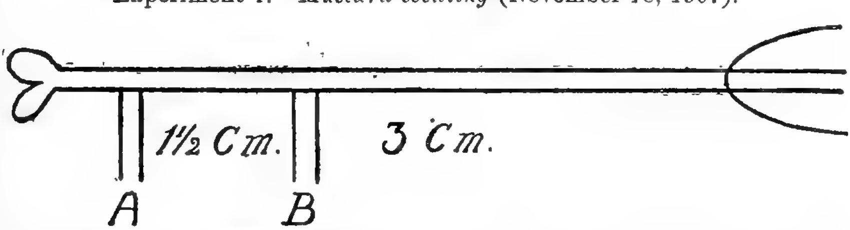
The undifferentiated nature of some of the tissues used in these experiments, together with the great sensitivity of the observed phenomena to external conditions, would bring these phenomena under the head of propagation by activity of the 'ground tissue,' following Fitting's classification. The results obtained, as also consideration of the necessity of postulating some means of interaction between the various parts of a plant, enabling it to react as an organic whole to external and internal stimuli—again, the existence of such adaptations to environmont as are shown in the trophic reactions common to all plants, and in the rather specialised cases of response to tactile stimuli in climbers—lead to the conclusion that the power of propagating excitation, far from being a rare and specialised phenomenon in vegetable tissues dependent on special fibrillar structures, is innate in every normal cell, and occurs freely wherever the protoplasmic continuity between cell and cell is at all considerable.

Transmission in Plants.—Selected Photos.

PLATE I.



Experiment 1.—*Mustard seedling* (November 18, 1907).

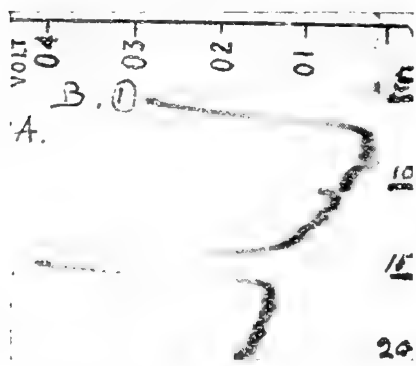


Two successive 'diphasic' responses to thermic excitation. Duration of double phase = 2 min., distance = 3 cm. The two interpolated smaller deflections are by $\frac{1}{100}$ volt sent to the preparation.

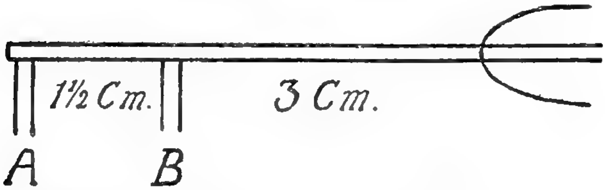
N.B.—The reader is advised that the records are taken (and reproduced) so that current from A to B gives deflection to the right, and current from B to A deflection to the left, in accordance with the diagram given below Exp. 1.

The letter B on the photograph indicates that B is 'zincative' (=galvanometrically negative to A). The letter A indicates that A is zincative to B. All other records are taken on the same plan, *i.e.*, deflection to the left indicates action at B, deflection to the right action at A.—(*A. D. W.*)

PLATE II.

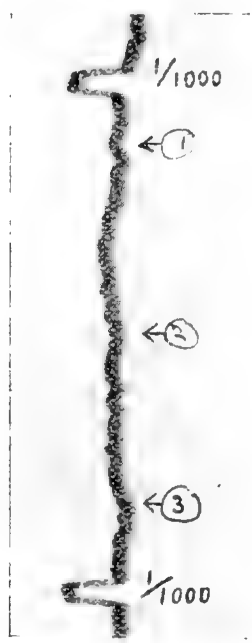


Experiment 2.—*Mustard seedling* (November 20, 1908).
(Transverse section at A.)



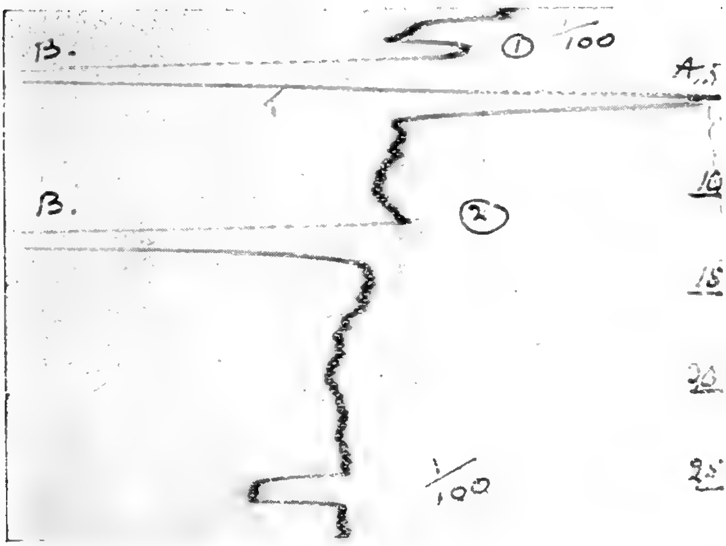
Two successive 'monophasic' responses to thermic excitation. Duration of single phase = nearly 2 min.

PLATE III.



Experiment 3.—*Electrocuted mustard seedling* (November 20, 1907).
No response to thermic stimulations at 1, 2, and 3. The deflections at beginning and end of experiment are by $\frac{1}{1000}$ volt—*i.e.*, the resistance is lower than in Experiment 1, where the interpolated deflections are by $\frac{1}{100}$ volt.

PLATE IV.

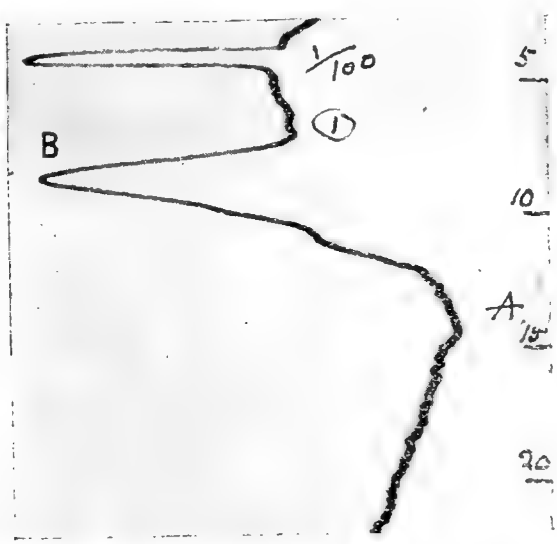


Experiment 4.—*Pea seedling* (November 28, 1907). Diphasic and monophasic responses to two successive excitations by heated platinum loop of wire.

Distance between leading-off electrodes equals about 1·5 cm., and the same distance between excited and led-off regions.

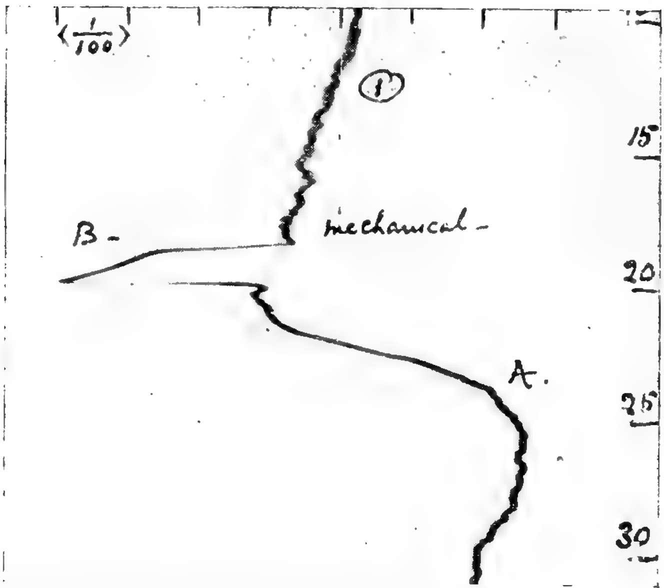
Deflections at beginning and end of experiment are by $\frac{1}{100}$ volt.

PLATE V.



Experiment 5.—*Pea seedling* (November 28, 1907). Doubtful diphasic response to thermic excitation.

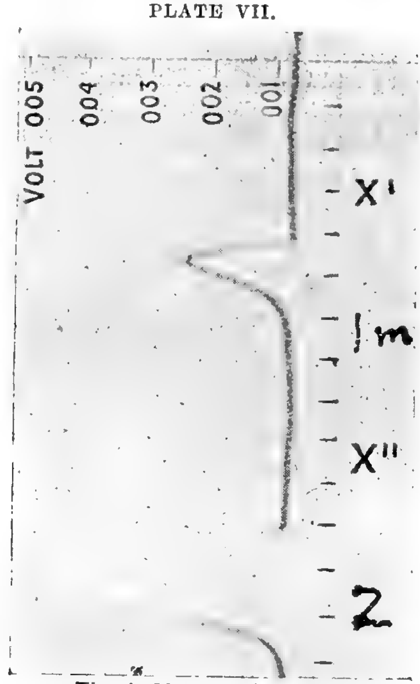
PLATE VI.



Experiment 6.—*Pea seedling* (November 28, 1907).

Doubtful diphasic response to mechanical excitation by a scissors cut at 2·5 cm. from the led-off region. The time interval between cut and response was estimated at about 30 secs.

PLATE VII.

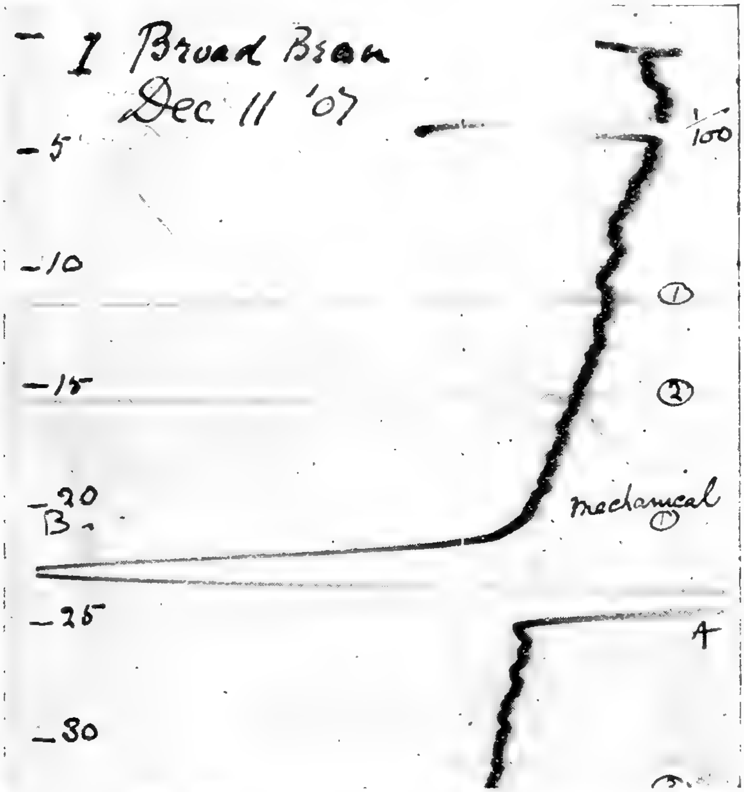


Time in 10 seconds in the vats.

Experiment 7.—*Pea seedling* (December 3, 1907).

Two successive monophasic responses to thermic stimulations, X′ and X″ at 2·5 and 1 cm. respectively from the led-off region. The record shows the lost times to be 5 secs. for X′ and 10 secs. for X″, measured from the end of the bar signalling the application of heat for 10 secs. The result is anomalous, inasmuch as the shorter distance is associated with the longer time and the greater response, and illustrates the danger of accepting speed of transmission calculated from such data. In subsequent experiments we used shorter periods (*i e.*, ½ sec.) of heating by stronger currents.

PLATE VIII.



Experiment 8.—*Bean seedling* (December 11, 1907).

'Diphasic' response to mechanical excitation (compression) at a distance of 8 cm. from the led-off region. This plant gave no response to thermic excitation.

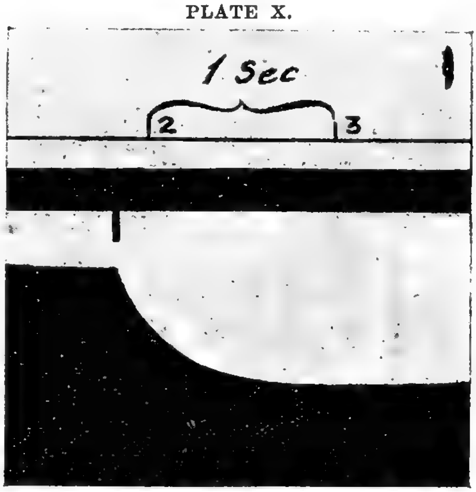
In the next experiment on the same plant mechanical excitation was followed by a monophasic response.

PLATE IX.

Experiment 9.—Same plant.

'Monophasic' response to mechanical excitation 4 cm. from the led-off region. At this distance thermic stimulation was followed by a small response with an apparent latency of 20 secs. This, if a true instance of transmitted excitation, gives a speed value of 2 mm. per second.

PLATE X.



Experiment 10.—*Bean seedling.*

Electrometer record of the local response to localised mechanical excitation, by a blow from a lever fixed to an electromagnet, the shadow of the lever being cast on the same plate as that of the electrometer so as to signal the instant of excitation. The local response exhibits no appreciable lost time.

PLATE XI.

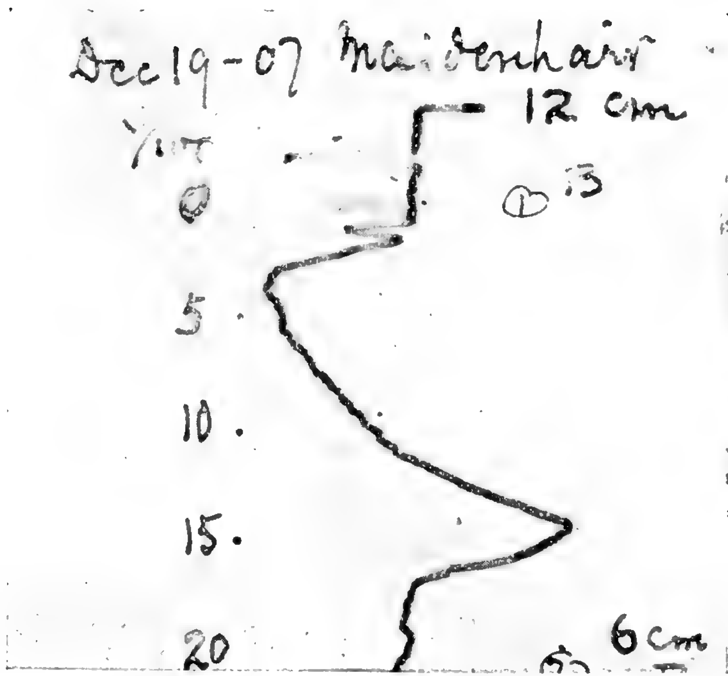
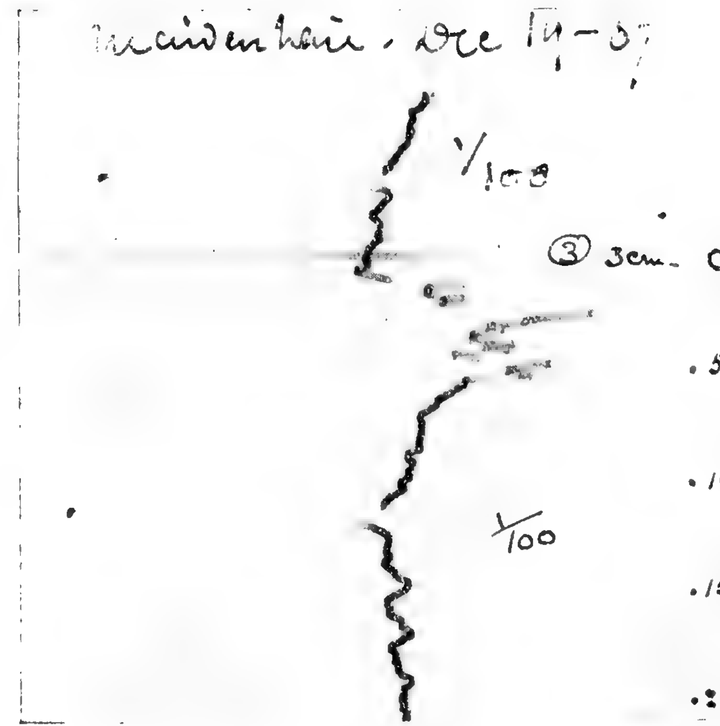


PLATE XIa.



Experiment 11.—*Petiole of maidenhair fern.*

Thermic excitation at a distance of 12 cm., followed by a double (?) diphasic response commencing about 30 secs. after excitation—*i.e.*, giving a speed equal to 4 mm. per second.

This experiment was further remarkable by reason of distance between exciting wire and leading-off electrodes, *i.e.*, 12 cm.; double 'diphasic' response, short and long; definite lost time of transmission; subsequent augmentation of conductivity; 'storm' of disturbance after the second and third excitations.

Fatigue. By WILLIAM McDOUGALL, *M.A., M.B.*

[Ordered by the General Committee to be printed *in extenso.*]

THE study of fatigue must always be of the deepest interest from the point of view of pure science, because in studying fatigue we are studying the sources of human energies, the modes and conditions of their operations, and, above all, their limitations. But the general speeding up of life, which is the most striking characteristic of modern civilisation, and which affects all classes at all ages from early childhood onwards, is rendering the study of the problems of fatigue a matter of the most urgent practical importance, and the scientific world has not been slow to recognise the fact.

The physiologists of the laboratory have studied fatigue in its most elementary manifestations, in the various organs and tissues, and at its ultimate and secret source, the cell. The psychologists have devoted much ingenuity to the study of the experimentally induced fatigue of the human organism as a whole, seeking specially to find means of measuring the degrees of fatigue and their influence upon the efficiency and the development of the various powers of mind and body. The physicians have discovered in the chronic fatigues produced by modern conditions of life the source of a large range of disorders which seem to have been unknown to, or at any rate unrecognised by, our forefathers. There is no ground on which the problems of mental and of bodily processes are so intimately and inextricably bound up together. There is no field of scientific research in which there is more need of co-operation between the various classes of workers, the physiologists, the medical men, the psychologists, and the sociologists; there is no biological problem in dealing with which it is more necessary to keep in mind both *the organ* and *the organism* in all their aspects.

On an occasion of this kind it is, I think, proper that we should attempt to effect some synthesis, some fruitful combination of the conclusions and the hypotheses indicated by the work done along these different lines. I shall hope, therefore, for your indulgence if I venture to offer you one or two speculative suggestions as contributions towards such a synthesis, suggestions whose only justification must be the degree of success with which they enable us to occupy the more comprehensive view-point in face of the problems of fatigue.

Our English word 'fatigue' is a most comprehensive one. Wherever there is evidence that organic activity results in diminished capacity of the organism to carry on any of its functions, there we commonly recognise *fatigue.*

Of all the manifestations of fatigue the most familiar are the *subjective*; of these subjective symptoms we must distinguish at least three classes:—

(1) Local sensations of fatigue, more especially in the muscles.

(2) The sense of feeling of *general tiredness*, of limpness, and general incapacity for effort.

(3) The experience we call *sleepiness.*

The first of these I want to dismiss with a single observation. You may get this sensation of local fatigue in the acutest form by holding out a limb—say the arm—for a few minutes against the pull of gravity.

After a few minutes you begin to experience in the muscles of the shoulder a disagreeable sensation which grows rapidly more intense until, after about five minutes, you feel that you can hardly support it. But, if you persevere, you find that there is no impossibility about doing so; the disagreeable or painful sensation grows but little more intense, if at all; you may continue to hold out your arm, and after half an hour there will be little more discomfort than after five minutes.

Put alongside that the fact that most good hypnotic subjects will in hypnosis keep a limb held up against the force of gravity for long periods without showing any tendency to relax it, or any other symptom of fatigue.

Facts of this order seem to show clearly that such local fatigue-sensation is protective in function; that it sets in long before there is any question of exhaustion of, or serious injury to, the tissues concerned through over-action. They show that the organism has need of some protection against the possibility of self-injury through excess of activity.

And this conclusion may serve to direct our attention to the possibility of a similar function being performed by other manifestations of fatigue.

In connection with the other two classes of subjective symptoms—tiredness and sleepiness, I would draw your attention to certain experiences of a kind that are probably familiar to all of you.

I sit reading in the evening some difficult technical work until, as midnight approaches, I feel thoroughly tired and sleepy, my eyes smart and will hardly keep open, my head is dull and heavy and aches a little, my whole body and my limbs feel heavy and incapable of alert movement. I then take up some thrilling story or other fascinating piece of literature; whereupon all my subjective symptoms of fatigue, both tiredness and sleepiness, disappear, and I read keenly for perhaps two hours, when I again begin to feel both tired and sleepy. Now suppose a continuation of the evening's history which is less familiar: some exciting event takes place just as I am about to go to bed—the house takes fire or a burglar breaks in, or a friend comes in with important and interesting news that demands immediate action. Again all the symptoms of fatigue disappear, and I can perform another spell of work at high pressure and without objective symptoms, and with little if any objective trace of fatigue—*i.e.*, without appreciable diminution of efficiency.

Facts of this order show, I think, clearly that what we commonly call fatigue, with all its diverse symptoms, objective and subjective, is no entity, that it is not due to any one kind of change in the organism; and they show that fatigue is never *absolute*, but is always *relative*. That is to say, the symptoms of fatigue are always the expression of the relation between at least two things—between, on the one hand, the work to be done, and, on the other hand, the amount of energy available at the moment for doing the work; or, in more technical language, the symptoms of fatigue are the expression of a change in the ratio between the available energy (the energy in an active, living state at the moment) and the resistance which that energy has to overcome. If the task in hand is intrinsically uninteresting, the energies brought into play, liberated within the organism, or transformed from the potential to the active state, are small in quantity; therefore a small amount of work, producing a small increase of the resistances to be overcome, suffices to raise the ratio of resistances to energies above the normal, and therefore to produce the symptoms of fatigue ; whereas if the circumstances are such as to bring into play greater stores of the potential energy of the organism, a much greater amount of work may be produced by the organism (whether bodily or mental work) before the ratio of the resistance to the available energy rises to the point at which symptoms of fatigue appear.

Reflection upon these familiar experiences yields then the two propositions on which I invite you especially to concentrate your attention, because I believe they may be the two master-keys to all the problems of fatigue—at any rate to those of fatigue of the nervous system. They may be briefly stated as follows :—

(1) Fatigue of the nervous system is a state in which the ratio of the resistances to the active energies is raised above its normal value, either through increase of the magnitude of the resistances or through diminution of the quantity of disposable energy.

(2) The function of the resistances is essentially the limitation of activity ; they are thus protective of the energy of the organism ; they prevent the organism exhausting its store of potential energy through unduly prolonged, intense, or widespread activity.

If these propositions are well founded we must, in order to understand fatigue, have good working conceptions on the one hand of the sources of the energies concerned and of the conditions and nature of their operations in the nervous system, and on the other hand of the nature and seat of the resistances that limit and preserve these energies.

It has recently been contended, notably by Bethe[1] in Germany and by Deschamps[2] in France, that the nervous system is not the seat of the liberation of any energy, or at any rate that such liberation is no part of its specific functions, but that it merely distributes the active energies supplied to it by *stimuli* of all kinds and by the various organs of the body. I think most of you will agree with me in holding that this view is quite unacceptable, and that the activity of the central nervous system does essentially and always involve liberation of energy, transformation of energy from the potential to the active form, and a consumption or using up of stores of potential energy. Verworn,[3] who has made himself the protagonist of this view, seems to me to have proved it by his own experiments and those of his pupils, although, even without these particular experimental results, there was hardly room for doubt about the matter. Further, Verworn's experiments on the spinal cords of frogs confirm the view (about which also there was little room for doubt apart from these experiments) that fatigue may be produced by either of two processes, and that it commonly is produced by their conjunction, namely (1) the process of accumulation of waste products of metabolism, CO_2, lactic acid and other substances ; (2) the using up of stores of potential energy through excess of katabolism over anabolism. The former is called by the Germans 'Ermüdung,' the latter 'Erschöpfung,' and some English writers have proposed to use the words fatigue and exhaustion in these two senses, as the equivalents of these German words.

[1] 'Zur Theorie der Zentrenfunktion.' *Ergebnisse der Physiologie*, Bd. v.
[2] *Les Maladies de l'Énergie*, Paris, 1908.
[3] 'Die Vorgänge in den Elementen des Nervensystems.' *Zeitsch. f. Allgemeine Physiologie*, Bd. vi.

I do not think we can profitably specialise these words in this way;[1] but if not we must have new words, for there can be little doubt that both processes take part in the production of fatigue, and we must distinguish between them and hold fast the two conceptions.

The question then arises, What are the seats within the nervous system of these two processes, 'Erschöpfung' and 'Ermüdung'? Verworn's view may perhaps claim the adherence of a larger number of physiologists than any other. It is very simple. According to this view, the cell-bodies, or 'ganglion cells,' are the seats, or at least the principal seats, of both processes, and both result in a diminished katabolism and output of energy by the cell-body. 'Erschöpfung' is thus, according to this view, a strictly local process, affecting only the bodies of the nerve-cells involved in any activity; while 'Ermüdung' is both local and general, because the cell-body is liable to be poisoned not only by the waste products of its own activity, but also by those of the metabolism of other nerve-cells and of other tissues of all parts of the body, especially the muscular tissues; for these waste products, wherever formed, may pass into the blood and lymph and so may reach the 'ganglion cells.'

Now I venture to say that this picture of the nature of fatigue of the nervous system is very much too simple; the conceptions are, I contend, true and useful, but inadequate to the explanation of the complex manifestations of fatigue which meet us as soon as we consider the organism as a whole; and they are inadequate also for the explanation of many of the special and local manifestations of fatigue.

The picture needs, it seems to me, to be complicated by two most important additions. First, Verworn's scheme takes little or no account of the resistances that the nervous energies have to overcome. Now if with him we regard the cells as seats of explosive decompositions and the nerve-fibres as freely conducting excitations, either as purely physical processes or, with more probability, as physico-chemical processes involving metabolic changes similar to those that occur in the cell-bodies, then it is obvious that there must be points or parts of the nervous tracts which delimit functional units and groups of units; else, instead of the orderly sequence of nervous excitations which normally follow upon any stimulation, the excitation would spread indefinitely throughout the nervous system, soon producing inco-ordinate general activity and a rapidly ensuing general exhaustion; in the way the results of which we see in the convulsions of strychnine poisoning.

Now the question, Where, in what structures, do these *resistances* reside? is one of secondary importance perhaps, so long as we recognise their nature and function. Still, it is a question of some interest. In a recent paper Verworn recognises the existence of resistances and assigns them, like all the other peculiarities of the central nervous system, to the cell-bodies.[2] To that view serious objections may be raised. To mention only one, it is difficult to suppose that the cell-bodies are the seats both of explosive decompositions which liberate energy and also of the resistances which delimit the paths by which the excitation spreads towards the different

[1] Because we need the word 'fatigue' to denote the state of diminished efficiency of the organism as a whole commonly produced by these two processes in conjunction, and we need the word 'exhaustion' to denote the extreme degrees of the state resulting from excess of metabolism over anabolism.

[2] 'Die Cellularphysiologische Grundlage des Gedächtnisses,' *Zeitsch. f. Allgemeine Physiologie*, Bd. vi.

nerves. On the other hand, there are many considerations tending to show that the principal seats of these resistances may be the synapses or places of junction of the neurones. I have not time to attempt to display the strength of the grounds of this assumption, and most of you are familiar with them.[1]

If we assume that the synapses are the seats of the resistance, and that the process of transmission of the impulse across the synapse is one that is very liable to result in a raising of the resistance of the synapses, then we have a conception which enables us to account satisfactorily for many manifestations of fatigue. I will point out a few of the facts which seem to point to the synapse rather than to the cell-bodies as the principal seats of the increased resistance. It has long been notorious that nerve-fibres are but little, if at all, liable to fatigue; and there is good reason to believe that the cell-bodies also are fatigued, not easily or rapidly, but only under prolonged activity or when deprived of the normal means of recuperation—deprived, that is, of the normal blood-supply. Yet we have evidence that local fatigue may be rapidly induced, and may as rapidly pass away, in the various levels of the nervous system.

Such local fatigue occurs in the reflected arcs of the spinal cord if a stimulus is continuously applied to the afferent path.[2] It occurs in the motor region of the cerebral cortex if one spot be continuously or repeatedly stimulated.[3] It occurs still more readily in the higher levels of the brain concerned in perception—*e.g.*, in all the cases of ambiguous figures which may be perceptually interpreted in two or more different ways, and of which the different modes thrust themselves alternately upon consciousness. I have studied these alternations and shown reason to suppose that a rapidly induced local fatigue of the higher cortical paths concerned is the principal condition of this alternating activity.[4] In the same way the extreme liability to fatigue of the paths of the higher cortical levels seems to underlie the extreme instability of all our thought processes; the fact that our attention can never be held fixedly and unchangingly upon any single feature of an object, but always, in

[1] See especially Professor Sherrington's *Integrative Action of the Nervous System*, Lecture I. In spite of all that has been written of the synapse in recent years, one still finds widely accepted the following argument: The nervous system consists of cell-bodies and nerve-fibres, therefore all those of its properties that are not displayed by peripheral nerves are due to the cell-bodies. Verworn himself still uses this argument, and so little is the conception of the synapse understood that Verworn, in a recent paper, interprets Sherrington as meaning by the term 'synapse' the place of junction of the axis cylinder and the cell-body of a single neurone. That, I take it, is implied when he writes, 'Goldscheider und Sherrington denken an die Uebergangstelle des Nerven in den Ganglionzellkörper, an die "Synapse," wie Sherrington sich ausdrückt' (*op. cit.*, p. 134). Sherrington inclines to the view that the process of transmission of the excitation across the synapse is a purely physical one (*op. cit.*, p. 17); but if, as he also inclines to believe, it is a process very readily affected by the presence of toxic substances in the blood, and if it has the effect of immediately and temporarily raising the synaptic resistance (fatigue), and of ultimately leaving it (when the fatigue effect has passed away) permanently diminished (habit), these effects would seem to demand for their explanation the assumption of some metabolic activity at the synapse. In a paper in *Brain* (vol. xxiv.) I have adduced other arguments in support of the assumption of intercellular substances, the seats of synaptic metabolism of a highly specialised kind.

[2] Sherrington, *op. cit.*, p. 214.

[3] A. G. Levy, 'An Attempt to Estimate Fatigue of the Cerebral Cortex,' *Journ. of Physiol.*, vol. xxvi.

[4] 'Physiological Factors of the Attention-process,' *Mind*, N.S., vol. xv. p. 340.

spite of all voluntary efforts to the contrary, passes on from feature to feature or plays to and fro over the object of thought.

In all these cases we seem to be dealing with a rise of the resistance of a nervous path rapidly induced by its activity and as rapidly passing away; a rise of resistance which serves to divert the excitation process from the path to some other channel, and so to prevent the injurious effects of a too-prolonged activity of any one path.

These are manifestations of local fatigue, of increase of the ratio of resistance to energy, induced not by diminution of energy, but by increase of strictly local resistance.

Again, experiments with the *ergograph* have been used much in the study of fatigue, but one very interesting feature of such experiments has been unduly neglected I think. I draw your attention to it in this connection, because it seems to bear out the view I am setting forth.

The subject of the experiment has to lift a heavy weight repeatedly at brief intervals, by bending as far as he can his middle finger. Fatigue very soon manifests itself in the form of a diminished extent of the bendings of the finger. Now if you carefully observe the subject as he continues to repeat his efforts, you will usually see that, while at first he contracts only the muscles immediately concerned in the flexion of the finger, other muscles come into play as the flexions become diminished in extent; first the muscles of the upper arm, then those of the shoulder, then those of the trunk, still later the muscles of the lower limbs and of the arm and shoulder of the opposite side, and even those of the face, jaw, and neck on both sides. There takes place, in short, a spread or march of the excitation (not unlike the march of Jacksonian epilepsy) from the motor tract directly concerned in producing the flexion of the finger to adjacent motor tracts, then to successively more distant tracts.

Now this is just what must occur if, while the supply of liberated nervous energy is maintained at a high level of potential, and while the subject continues to direct it towards the one set of muscles, the resistances of the paths through which the excitation reaches the muscles are liable to be rapidly raised owing to the intensity of the process and to its repetition at brief intervals. The excitation will overflow, first into the most nearly connected tracts; later into those successively more remote, as the resistances of the more nearly connected tracts become in turn increased.

A very brief rest suffices to abolish, or to diminish in very large degree, any fatigue symptoms induced by ergographic work; and if in the ergographic experiments the intervals between successive bendings of the finger are made equal to several seconds, the evidences of fatigue are much diminished.

We have then abundant evidence of the rapid production of local increase of resistance in the central nervous system; and all that we know of the cell-bodies and of the axis cylinders makes it improbable that they can be the seats of these rapidly induced and very transitory local increases of resistance. Further, the fact that these local increases of resistance seem to be most rapidly induced in the higher levels of the central nervous system, where the connections between neurones must be regarded as least intimate and fixed, and to be least rapidly induced in the reflex arcs of the spinal cord, where the connections between afferent and efferent neurones are most firmly established, is in harmony with the view I am defending and seems unintelligible if the alternative view be adopted.

It seems probable that the resistance of the synapses is liable to be temporarily increased not only locally by the transmission of the nervous excitation across them, but also generally by the influence of the waste products of metabolism brought to them in the blood; that they are, in short, very subject to chemical influences of many kinds.[1]

If so, then such action of waste products upon them must play a large part in that general increase of the ratio of resistance to energy which constitutes general fatigue, and which manifests itself subjectively in general tiredness and in sleepiness; and also in the onset of sleep or general quiescence of the brain, the most important of the modes in which the organism protects itself against exhaustion.

If we provisionally accept this view, that the synapses are the principal seats of resistance, and that their resistances are liable to be thus increased both locally and generally, then the simple picture of fatigue which I have associated with the name of Professor Verworn becomes considerably complicated. In addition to local 'Erschöpfung' of the neurones, and to local and general 'Ermüdung' of them by waste products, the former of which means local, and the latter both local and general, diminution of energy supply, we recognise local and general increase of synaptic resistances. We have then, I think, a scheme much less inadequate to the explanation of those familiar and important peculiarities of fatigue to which I drew your attention in my opening remarks.

But I said there were two complications to be added to the simple Verworn picture. We have added the resistances varying from local and from general causes. The second complication concerns the sources of the energies involved in bodily and mental activity.

According to the Verworn scheme every cell-body is, I take it, to be conceived as capable of generating or transforming or liberating a certain quantity of energy, which, up to a certain upper limit, varies with the intensity of the stimulus applied to the cell; and this energy is to be regarded as finding its field of operation wholly within the neurone or the particular small functional group of neurones within which it is liberated; and all neurones are of appreciably equal value in this respect.

But there is another conception of the mode of operation of nervous energy which goes back at least as far as Descartes; the conception—namely, that the energy liberated by chemical change, by katabolic process, in one part of the nervous system may be conducted through the nervous channels and may operate in other parts of the nervous system. This may be called *the hypothesis of the vicarious usage of nervous energy*. Now it seems impossible to get the physiologists of the laboratory, the physiologists who are chiefly concerned with the organs rather than with the organism, to consider this conception seriously and on its merits. If they occasionally refer to it, it is only to put it aside contemptuously as a naïve survival from the dark ages. Yet those who are in the habit of dealing with the problems of the organism as a whole, the physician and the psychologist, constantly make use of this conception, for they find it impossible to make progress in the understanding of their problems without it.[2] That fact gives the conception a claim to a more serious consideration than it has commonly received from the physiologists.

[1] There is something to be said for the view that they are the seats of the primary and principal influence of various drugs, possibly of alcohol, chloroform, strychnine, and others.

[2] The necessity of conceiving nervous energy in this way was urged as long ago

The conception towards which the study of the organism as a whole points is that the neurones of the afferent side of the nervous system (including the cerebellum) constitute a great common reservoir of free energy, in which the head of pressure varies from moment to moment with the ratio of the in-flow to the out-flow, and on which all efferent paths may draw in turn when they come into activity.

As to the sources from which this reservoir of free energy is supplied, no doubt every one of its constituent neurones is capable of making its contribution, and especially all those directly connected with, and stimulated through, the sense-organs.

But we shall never understand the problems of fatigue, or any other of the great problems of the brain, until we adequately recognise certain special sources of supply. And the study of fatigue serves to bring into prominence the importance of these special sources of energy.

In psychology we speak of instincts or innate dispositions to action, and we recognise that the constitution of every human being comprises a certain number of such instinctive dispositions, and that when any one of these is awakened, whether by sense-impression or idea, the subject experiences a state of emotional excitement, and an impulse, a desire or aversion, a strong conation or felt tendency towards some kind of action. We recognise that under the driving power of such an impulse the subject can achieve tasks, can put forth quantities of energy, such as are impossible for him in the absence of any such conative-affective excitement.[1]

It is for the physiologist to discover if possible the neural seats and bases of these innate dispositions. Recent work by Pagano seems to indicate that they may perhaps be found in the basal ganglio of the brain.[2]

But however that may be, it seems safe to assume that these powerful impulses, which we experience in conjunction with our emotional excitements, and which enable us to energise in a way quite impossible in their absence, have nervous correlates, and that the physiological correlate of such an impulse is a great liberation of energy in some centre or part of the central nervous system, which energy augmenting greatly the disposable free energy of the brain, can be utilised in the performance of any kind of action undertaken for securing the satisfaction of the impulse ; and it seems that such an accession of energy can overcome the increased resistances obtaining in a state of moderate general fatigue, abolishing more or less completely in so doing both the objective and the subjective symptoms of fatigue, because the great accession of energy lowers the ratio of resistance to energy.

It is the possibility of these sudden accessions of energy that has rendered well nigh futile all the many attempts hitherto made to obtain reliable objective measures of degrees of fatigue of the organism as a

as 1886 by Dr. Hale White (*Lancet*, vol. ii. 1886, p. 161; see also *Brit. Med. Journ.*, October 17, 1908), who proposed to use the word 'neurorrheuma' to denote nervous energy so conceived. Among many others who have approved of this conception are Sir Victor Horsley (Hughling's Jackson Lecture, *Brain*, vol. xxix. p. 448) and Dr. S. G. Sharkey (Presidential Address to the Neurological Society, *Brain*, vol. xxvii. p. 12).

[1] For a fuller discussion of the *rôle* of these innate dispositions in the maintenance of human activities, I may refer to my *Introduction to Social Psychology*.

[2] *Archives Italiennes de Biologie*, 1906.

whole.[1] Dr. Rivers[2] has recently shown how great a disturbing factor in ergographic work is 'interest,' and the awakening of interest on the part of the subject means essentially the bringing into play of one or more of these special sources of energy.

Again, in such fatigue experiments as those of the Kraepelin school, the fatigue effects are constantly complicated, obscured, and rendered doubtful by variations of interest or of impulse which show themselves in spurts of all sorts.[3]

It is only when we take into account these special sources of energy that we can begin to understand the way in which, under circumstances that powerfully evoke our native impulses, we can execute without fatigue tasks which in less favourable circumstances would render us prostrate with every symptom of fatigue.

Professor James, in a recent lecture entitled the 'Energies of Men,'[4] has dealt, in his brilliant way, with this aspect of our problem; he brought forward many examples of the way in which, under conditions suited to bring their powers most fully into play and to sustain their interest at a maximum, men may achieve incredibly severe and sustained efforts. He quoted especially the case of Colonel Baird Smith, who conducted the siege operations before Delhi during the Sepoy Mutiny; showing how for months he hardly ate or slept, or rested in any way, but worked almost continuously at tremendous pressure without showing or feeling fatigue, and how then, when the end came, and the circumstances ceased to demand and excite his efforts, he collapsed an inert, emaciated, almost lifeless invalid.

Such cases illustrate again my main point—namely, that fatigue is relative, is the expression of a rise of the ratio between resistances and energies, and how, if the conditions are such as effectively to call into play all the great special sources of energy, this ratio may be kept from rising above the normal, until the whole organism approaches absolute exhaustion; whereas, on the other hand, under conditions of boredom, the ratio is very readily raised above the normal.

If, then, there is any truth in what I have said of these sources of energy and of the vicarious usage of energy, it follows that we have to recognise as a second condition of general fatigue, in addition to the presence of products, of metabolism in the blood, a diminution of the disposable energy, due to a diminished metabolism of the neurones in general, and of these special sources of energy in particular, and the

[1] MM. Binet and Henri have shown the inadequacy of the various methods employed previous to the date of publication of their work—*La Fatigue Intellectuelle* (1898); and in a recent critical study of the principal methods Messrs. Ellis and Shipe (*American Journ. of Psychology*) have arrived at the conclusion that none of those investigated by them are reliable.

[2] 'The Influence of Alcohol and other Drugs on Fatigue.' London, 1908.

[3] The Kraepelin methods, I may remark in passing, seek to avoid these disturbances by keeping interest at a minimum. But the human subject is not easily kept in such a state; he will become interested if only in the approaching end of his task, and hence great irregularities. In view of these difficulties I have suggested a method of estimating fatigue, which follows the opposite principle and seeks to keep interest at a maximum throughout, the task set being of the nature of a sprint; and I venture to think that this is the sounder and more hopeful principle to follow; see 'A New Method for the Study of Concurrent Mental Operations and of Mental Fatigue' (*Brit. Journ. of Psychology*, vol. i.).

[4] *Philosophical Review*, 1907.

possibility of general fatigue of this nature is, I think, especially important from the point of view of the physician.

The long continuance of the chronic fatigues with which the physician so often has to deal seems to show that, in many cases at least, these are not toxic fatigues (the only kind of general fatigue admissible under the too simple Verworn scheme). They seem to imply the exhaustion of some of the sources of energy, which rendering the maintenance of a due general pressure or potential of free energy impossible, keeps the ratio of resistance to energy high in all parts of the nervous system.

I have already kept you too long, but I should like, greatly daring, to suggest how the conception of fatigue as an increased ratio of resistance to energy may possibly help us in arriving at an understanding of some nervous disorders.

A due balance between resistances and energies is essential to health, and it seems possible *à priori* that the balance may be disturbed by disorder primarily affecting either factor.

Suppose that, as an innate constitutional peculiarity, the resistances are deficient relatively to the energies in an otherwise normal or well-endowed brain; we should expect to see the possessor of such a brain an excitable sensitive person who, the great protective system being deficient, easily works himself to the point of exhaustion; exhaustion rather than fatigue will be his peculiarity. He is readily provoked to a great and rapid output of energy, and his brain does not easily return to rest; general excitement is slow to die away, and he finds difficulty in sleeping after any effort, for the condition of increased and predominant resistance is not easily attained; the system remains uselessly at work and wears itself out; there follows exhaustion secondarily developed, owing to the deficiency of the protective system of resistances. We should then get the typical picture of the hereditary or born neurasthenic; the disorder is brought on by any strenuous course of life, and its early stages are characterised by hyperæsthesias of all sorts, undue sensitiveness to all sense-impressions, general irritability or irritable weakness, insomnia, increased reflexes; the patient may have the power of working sometimes extremely effectively for a short time, but such work soon leads to exhaustion and leaves the patient incapable for a long time of again getting up a sufficient head of nervous pressure to renew his labours. It is, I think, in harmony with this view that some of our most brilliant and original intellects have shown marked neurasthenic tendency *e.g.*, Charles Darwin and Herbert Spencer.

The neurasthenia induced by shocks—*e.g.*, the mental and physical shocks of a railway accident—may possibly be brought into line by the supposition that the brief and general overstimulation of the nervous system, which was too sudden to allow the increase of resistances to play their normal protective part, has more or less paralysed the synaptic process, so that they no longer are capable of building up and maintaining the due resistances, and again irritable weakness dominates the scene.

In this way it seems to me we may perhaps account for the paradoxical character of neurasthenia, for its combination of excess and defect of energy, the difficulty of getting up steam, the easy and rapid running down of the effort, if an effort is successfully initiated.

There is another great type of functional disease—*hysteria*, so like and yet so different from *neurasthenia*, which seems to be also a form of chronic fatigue.

Here possibly the primary evil is a constitutional defect of the energies relatively to the normal resistances. Such relative defect is apt to be brought to light by any course of life that makes considerable demands on the nervous energies, and shows itself in the failure to maintain the unitary functioning of all the many neural systems and sub-systems that make up the brain. The systems tend to become functionally separated from one another, because the supply of energy is insufficient to overcome the resistances of the highest levels of the brain and to keep open the connecting channels; hence each neural system tends to function independently of the rest, and each, being removed from the reciprocal control and inhibition normally exerted by all the rest, may function in excess, or, on the other hand, may lie dormant. Hence we get the curious pictures of overactions combined with partial defects of action, of hyperæsthesia with anæsthesia, of local contracture and paralysis, of incapacity for effort and violent convulsions, of fixed ideas and of easily changed convictions, of extreme suggestibility and extreme obstinacy. And in extreme cases we get the falling asunder of the neural basis of unitary personality into two or more functional systems, each of which becomes more or less fixed in its isolation; and we thus get the most strange of all the functional disorders—the cases of divided or multiple personality.

Body Metabolism in Cancer.—Report of the Committee, consisting of Professor C. S. SHERRINGTON (*Chairman*) *and* Dr. S. M. COPEMAN (*Secretary*). (*Drawn up by the Secretary.*)

THE report now submitted has reference to a continuation of work on the chemical constitution of the gastric secretion in cancer, of which a preliminary account was communicated to this Section at the last annual meeting.

Professor Benjamin Moore and his colleagues had published in the 'Proceedings of the Royal Society' the account of an investigation dealing with this question in the human subject, in which they set out reasons for their conclusion that the amount of free HCl in the gastric secretion of patients suffering from cancer, in situations other than the stomach, was invariably diminished or might even be absent altogether.

In view of the results obtained by these observers it was decided, thanks to the cordial co-operation of Dr. Bashford, the Director of the Imperial Cancer Research Fund Laboratories, to make use of the large amount of material at the disposal of that fund for the purpose of determining, with other constituents, the relative amount of physiologically active HCl in the stomach contents of mice suffering from transplanted and from 'spontaneous' cancer; controlling the results by examination of normal mice under identical conditions of feeding and period of digestion.

The experiments of which this report forms a brief summary were commenced in December 1905, and have been continued up to the end of June in the present year. A detailed account of the work will appear in the forthcoming number of the 'Proceedings of the Royal Society.'

It should be premised that under the term 'physiologically active hydrochloric acid' is included both the free acid and that combined with proteids and nitrogenous organic bases. Much misconception has arisen in the use of the terms 'free' and 'combined' as applied to HCl in the gastric contents; but inasmuch as the latter may have been 'free' a short time previous to its estimation, the exclusive determination of 'free' HCl alone cannot but lead to fallacious conclusions. The method adopted, after careful consideration, for the estimation of the physiologically active HCl is based on Luttke's modification of Volhard's volumetric estimation of chlorides by precipitation with excess of standard silver nitrate solution in the presence of free nitric acid, and subsequent determination of the excess of silver nitrate by standard ammonium thiocyanate, using iron-alum as indicator.

By estimating (*a*) the total chlorides and (*b*) the inorganic chlorides in an aqueous solution of the gastric contents, by this method, the physiologically active HCl $(a-b)$ is obtained. A further determination (*c*) of the total acidity with standard sodium hydrate, using phenolphthalein as an indicator, gives, in addition, the free organic acids $[c-(a-b)]$ in terms of hydrochloric acid.

It did not, at first, seem feasible to determine these constituents of the gastric contents in single stomachs, owing to their small weight (frequently not exceeding 0·5 gramme), and therefore estimations were made, in the earlier experiments, on batches of stomachs varying in number from six to sixty.

Later, by using $\frac{N}{50}$ or $\frac{N}{100}$ standard solutions in place of $\frac{N}{10}$ solutions and slightly varying the details of the method, it proved possible to make the estimations, with accuracy and comparative ease, with *single* stomachs.

In the first five series of experiments no account was taken of the period of digestion, the mice being simply removed from their cages while feeding. Under these conditions the results obtained somewhat unexpectedly indicated an *increase* in the secretion of physiologically active HCl in mice with transplanted tumours as compared with normal mice, the average amounts of HCl being 0·1752 per cent. and 0·1121 per cent. on 178 mice and 150 mice respectively.

Next, a number of experiments were made to determine, if possible, the usual period of digestion for normal mice; but the results obtained after periods of half an hour, one hour, and one hour and a half respectively showed that while, on the whole, more mice attained a maximum secretion of HCl in one and a half hours, many attained a maximum at one hour, and some even at half an hour. Parallel experiments were made with mice with transplanted tumours for the same period of digestion. Similar variations were found, for these periods, to those observed in normal mice, but with a general tendency to increase of HCl.

Summarising the results obtained in the experiments relating to definite periods of digestion, the examination of 245 stomachs from normal mice gave an average of 0·1456 per cent.; and of 290 stomachs from mice with transplanted tumours, 0·1673 per cent., for periods of one hour's digestion.

Thirteen single rat stomachs, weighing with contents from 2·5 to 10 grammes, were also examined. Six of these were from normal rats and seven from rats with transplanted tumours, the tumours varying in weight from 0·3 to 15 grammes. The former gave an average of 0·1427 per cent. HCl after one hour's digestion, while the latter gave an average of 0·1837 per cent. after the same period.

We have also had the special opportunity of examining fifteen single stomachs from mice with spontaneous tumours, which showed an average of 0·1929 per cent. HCl, also after one hour's digestion.

Hence, comparing the secretion of HCl during definite and indefinite periods of digestion in the stomachs of normal and 'cancer' mice, we found practically the same range of variations throughout, but with a general tendency towards *increase* of HCl in the case of 'cancer' mice.

The total number of experiments made, from which the averages referred to have been deduced, was about 150, involving from four to six estimations in each experiment.

These results are interesting not only as indicating that, chemically, the digestive process in mice is largely comparable with that in the human subject, but as confirming, and to some extent explaining, the observation made by Dr. Bashford in 1905 as to the general absence of cachexia in mice suffering from cancer.

Now, inasmuch as recent extensive statistics collected by Dr. Bashford from the various London hospitals have shown that cachexia, contrary to the general belief, is not a constant accompaniment of cancer in man, we might expect to find, in its absence, the same compensating influence as regards increased secretion of HCl in human beings afflicted with this disease.

As regards this point, however, so far as indicated by recent investigations, to which reference has previously been made, the opinion is prevalent that the reverse obtains; Moore, Palmer, and others having, indeed, asserted that there is a marked diminution or even an absence of HCl in the gastric secretion in malignant disease of organs other than the stomach.

These conclusions, however, have been mainly based on a determination of 'free' HCl only, in the fluid withdrawn from the stomach after the administration of so-called 'test meals'; but, as we have indicated, such estimations alone may easily lead to fallacious conclusions.

We felt that, inasmuch as our determinations of physiologically active HCl in the gastric contents of mice seemed to be in contradiction to results obtained in man as regards 'free' HCl, it was obviously necessary to repeat Moore's work, and at the same time, for purposes of comparison, to carry out a parallel series of estimations, by the same method that he had employed, in the work on mice. Examination was therefore made of the gastric secretion in the human subject as represented by the fluid withdrawn one hour after administration of a 'test meal' to patients suffering from cancer, which material we have been able to obtain through the courtesy of the surgeons to the Cancer, Middlesex, and Westminster Hospitals. Estimations were made both of the physiologically active hydrochloric acid by Volhard's method, as already described, and also, for comparison, of the free HCl by the inversion of methyl-acetate—the method employed by Moore and others.

Summarising these experiments, it was found that the estimations of free HCl more or less agreed with those of Moore in his later experiments, published in the 'Bio-Chemical Journal' (vol. i. p. 274), where he states the average of thirteen cases of cancer as 0·0515 per cent.; our average, also for a series of thirteen cases, being 0·0407 per cent. Moore, however, in thirteen previous cases[1] had recorded an average of only 0·0039 per cent., while Palmer, in fourteen cases, found an average of 0·0217 per cent.

Such discrepancies are not reassuring, but some explanation of them may be found in the varying periods of digestion selected by these observers—viz., from one to two hours. But it would seem that a more probable explanation is afforded by the evanescent character of the so-called 'free' HCl, to which reference has previously been made. In contrast to these results, the determination of the physiologically active HCl in our thirteen cases averaged 0·1626 per cent., five of them being above 0·18 per cent.

An unexpected difficulty arose in connection with the examination of a number of the earlier 'test meals' supplied to us, and to the results of which no reference is now made, by reason of the fact that, as we subsequently learnt, additions of varying amounts of water had been made in order to overcome difficulty experienced in the withdrawal of the stomach contents. Obviously, conclusions based on the examination of such diluted 'test-meals' can be of little or no value. To this point we think sufficient attention has not previously been directed.

Summarising the whole of the results of the work now recorded, it may be stated generally that in mice, the subjects of transplanted or spontaneous cancer, there is found, on the average, a definite *increase* of physiologically active HCl in the gastric secretion. As regards the human subject similar increase does *not* occur, while in some cases the amount is decidedly below normal. Nevertheless, it would certainly not appear justifiable to conclude that the amount of physiologically active HCl is always greatly diminished in cases of cancer in the human subject.

Further investigation not only of the variations in amount of HCl secreted, but of concurrent variations of the chemical constitution of the blood, on which the former are probably in large measure dependent, would appear to be most desirable. A commencement has already been made with regard to work on the blood and, incidentally, the urine also; work which, if the Committee be reappointed, it is proposed to continue.

Studies of Marsh Vegetation.—Report of the Committee, consisting of Dr. F. F. BLACKMAN (*Chairman*), Mr. A. G. TANSLEY (*Secretary*), Professor A. C. SEWARD, *and* Mr. A. W. HILL.

THE work mentioned in the report of this Committee for last year has been continued by Professor R. H. Yapp. Further experiments on evaporation in relation to the stratification of marsh plants, as well as various field observations, have been carried out at Wicken Fen. The experiments on *Spiræa Ulmaria* have been continued at Aberystwyth and Cambridge. Work was carried on at Wicken Fen in August, September, and November of 1907, and in January, April, July, and August of 1908. In addition to this, various other localities in the Fen Country and the Norfolk Broads have been visited.

A preliminary account of the vegetation of Wicken Fen was published in the 'New Phytologist' (March 1908), and it is hoped that further results will be ready for publication shortly.

[1] *Proc. Roy. Soc.*

The Structure of Fossil Plants.—Report of the Committee, consisting of Dr. D. H. SCOTT (*Chairman*), Professor F. W. OLIVER (*Secretary*), Mr. E. NEWELL ARBER, *and* Professors A. C. SEWARD *and* F. E. WEISS.

ONLY 1*l.* 11*s.* of last year's grant has been spent. The reason why so little of the money has been required is that the material necessary has not been available for the special investigations in hand. Two papers, based largely on specimens obtained by means of previous grants, have appeared this year :—

1. Professor F. E. Weiss, 'A *Stigmaria* with Centripetal Wood' ('Annals of Botany,' vol. xxii. April 1908).

2. Messrs. E. A. N. Arber and H. H. Thomas, 'On the Structure of *Sigillaria scutellata* and other Eusigillarian Stems' ('Proc. Royal Soc.,' vol. lxxx., April 10, 1908). [The full paper, in the 'Phil. Trans.,' will appear immediately.]

The Committee ask for reappointment, with a grant of 15*l.* to enable them to obtain new material as opportunity arises.

Sequence of Plant Remains.—Interim Report of the Committee, consisting of Professor J. B. FARMER (*Chairman*), Professor R. J. HARVEY GIBSON (*Secretary*), Dr. J. HORNE, Dr. MARR, Mr. CLEMENT REID, *and* Mr. FRANCIS J. LEWIS, *appointed to examine the Sequence of Plant Remains in the Peat Deposits of Teesdale and Stainmore (Cumberland and Westmorland) and the Western Portion of Iceland.*

THIS investigation was begun in Iceland last year. During September, a journey was taken through the S.W. of Iceland between Reykjavik and Fjlotshlid—a distance of about 130 miles—and the more extensive areas of peat were noted, and sections taken in the Reykir district and in the neighbourhood of Havnafjord. A considerable part of this area is covered with peat, the deposits varying in thickness from 3 feet to more than 15 feet.

Nearly all the peat deposits visited were found to be covered with 2 to 3 feet of extremely fine yellow dust having all the characteristics of loess. These deposits occur in broad shallow valleys and on gently sloping ground. No peat more than a few inches in thickness was observed at a greater elevation than 500 feet above sea-level.

For about 20 miles to the east of the Pjórsa River the ground is flat and covered with peat, generally exceeding 15 feet in depth. These deposits consist of almost equal quantities of fine dust and plant remains. The northern part of this district bordering on the Rángarvallasveit is generally covered with 3 feet of loess, but in the southern part near the coast the peat is generally well exposed.

The present vegetation of the loess-covered peat mosses consists of *Dryas octopetala, Empetrum nigrum, Calluna vulgaris, Selaginella spinosa, Salix lanata, S. herbacea, Vaccinium Myrtillus, Polygonum viviparum, Thalictrum alpinum.* Every section taken last year in the various districts visited showed the presence of one or sometimes two distinct forest beds of *Betula odorata.* The wood is large, some of the trunks being 15 inches in diameter. As far as the observations go at present, the sections within 100 to 200 feet above sea-level showed one forest bed, those at higher elevations showing two. Until more numerous sections are taken over wider areas it is impossible to say whether this feature obtains in all places.

The thickest peat beds are made up of *Scirpus cæspitosus,* and Carices; hardly any trace of Sphagnum has yet been met with in the Icelandic peat mosses.

The following section, taken near Havnafjord at 30 to 50 feet above sea-level, is taken to illustrate the general sequence of plant remains met with in other localities at about this elevation:—

1. Loess, 3 feet.
2. Peat formed of *Scirpus cæspitosus* and Carices, 4 feet.
3. Layer of *Betula odorata* remains, 2½ feet.
4. Peat containing leaves of *Dryas octopetala, Salix lanata, S. herbacea,* and numerous small *Salix* twigs, 1½ feet.
5. Scirpus and Carex peat.
6. Rock.

A large amount of material was brought back from the sections, some of this has yet to be worked through.

A full discussion of the various sections and the sequence of vegetation preserved in the peat is reserved for the final report.

The Committee asks for the renewal of the balance (27*l.*) of the grant made in 1907 for the purport of completing this investigation by examining other large peat areas in West Iceland, and for further detailed work over those peat areas located and partly examined last year. The Committee hopes to begin the investigation of the peat deposits of Stainmore this autumn or next spring.

The Committee further asks for a small additional grant of 10*l.* to be made to the balance of last year's grant, to be applied to the same purpose, as the expenses of the investigation—chiefly due to the expense of labour for cutting sections in Iceland—are larger than at first estimated.

Research on South African Cycads and on Welwitschia.—Second Interim Report of the Committee, consisting of Professor A. C. SEWARD (*Chairman*), Mr. R. P. GREGORY (*Secretary*), Dr. D. H. SCOTT, *and* Dr. W. H. LANG.

1. THE Welwitschia-material collected in Damaraland in 1907 (B. A. Report, 1907, pp. 408–409) has been investigated. The results are ready for publication, and it is expected that they will appear before the end of the year.

2. The leisure of Professor H. H. W. Pearson, who is carrying out the work, has been completely occupied with the work on Welwitschia, and he has not personally proceeded further with the investigations on Cycads referred to in the interim Report presented last year. Two correspondents living in the Cycad region are continuing the field-observations, especially with reference to pollination, and it is believed that definite results will shortly be forthcoming.

Studies most suitable for Elementary Schools.—Report of the Committee, consisting of Sir PHILIP MAGNUS (*Chairman*), Mr. W. M. HELLER (*Secretary*), Sir W. DE W. ABNEY, Mr. R. H. ADIE, Professor H. E. ARMSTRONG, Miss L. J. CLARKE, Miss A. J. COOPER, Mr. GEORGE FLETCHER, Professor R. A. GREGORY, Principal GRIFFITHS, Mr. A. D. HALL, Dr. A. J. HERBERTSON, Dr. C. W. KIMMINS, Professor L. C. MIALL, Professor J. PERRY, Sir H. R. REICHEL, Mr. H. RICHARDSON, Mrs. W. N. SHAW, Professor A. SMITHELLS, Dr. LLOYD SNAPE, *and* Profesor W. W. WATTS, *appointed to report upon the Course of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.*

CONTENTS.

INTRODUCTORY STATEMENT.[1] By Sir PHILIP MAGNUS, M.P.

REFORM in educational administration and in method of instruction has been more rapid during the last decade than for many previous years. This is, of course, due to the cumulative effect of national education. In England and Wales the Act of 1902 has fully realised the expectations of those who trusted to local interest to stimulate educational progress. Its defects, such as they are, have not yet been removed, but they are strictly limited in character and do not prevent improvements being effected in organisation and in teaching. Notwithstanding the political and religious differences that divide parties, educational measures of some importance have been added to the Statute-book during the life of the present Parliament. The educational concept has been widened so as to include physical training and the medical inspection of children, and efforts are being made to develop on more scientific lines the teaching of morality in its relation to civic duties. The discussion of this subject at the Moral Education Congress, to be held in London at the close of the present month, to be attended by representatives from all parts of Europe, will, I hope, bear fruit. As the outcome of the efforts of this Section of the British Association and of other societies, the unity of education is being more generally recognised. The barriers that separate primary, secondary, and university education are being partially removed, and the close connection of technical with each grade of education is more firmly established. In various directions, too numerous to be here indicated, advances have been made. Still the cry is that the foundations of a national system of education are not securely laid. In vain, it is said, we try to rear a solid and useful superstructure on the teaching given in our elementary schools. It fails to create a love of learning or serviceable manual skill. It meets with a too faint response in the child's mind and habits. It leaves the senses inadequately stimulated and the reasoning powers imperfectly developed. This partial failure of our efforts is not

[1] Ordered by the General Committee to be printed *in extenso*.

so much the fault of the teachers as of the system and the methods of instruction. The teaching helps, no doubt, in creating certain aptitudes and in imparting a limited amount of knowledge. But the aptitudes are not permanent and the knowledge is too soon forgotten. The training is defective as a preparation for practical pursuits, whether in the field, the workshop, or the home. As a consequence, the unemployed and the unemployable increase in numbers, and children seek the means of livelihood in occupations, such as messengers and newspaper-vendors, which open up no avenue to more useful and more remunerative employment. Some, it is true, by means of scholarships, scale the educational ladder and find situations in the overcrowded ranks of clerks; others—not many—enter the learned professions, in which a few succeed. As a remedy for this state of things compulsory attendance at continuation classes in day or evening schools is suggested; but the majority of parents are unable to afford to maintain their children till the age of sixteen or seventeen; only a few can do so, and the prospects of such children are in many cases improved.

Experiments have been, and are still being, tried in the way of establishing schools in which specific trades are taught and of combining industrial work with general instruction, but no sure method has yet been found of providing during a boy's or girl's school years the kind of training which affords a satisfactory substitute for apprenticeship, enabling a youth on leaving school to become at once a wage-earner. The difficulty has not yet been solved. I have long thought that the remedy may be found in a somewhat drastic change in the aim and methods of our elementary education in substituting very largely practical exercises for book-learning, and in grouping the necessary subjects of instruction around some kind of hand-work, whether in the workshop, in agricultural pursuits, or in the practice of the domestic arts. This fundamental change is now favourably regarded by many educational reformers here and abroad. Schools in which the teaching is mainly practical have been established in many parts of the world. They are more common in the case of boys than of girls; but it is equally, if not more, important that the training of girls should be on practical lines, and that manipulative skill should be developed during their school life. In the opinion expressed by Professor Smithells at a recent meeting of the Northern Union of the Domestic Economy Association I fully concur. He said: 'I believe, in fact, that in the household arts you have a direct educational instrument for conferring upon girls the very great gift of manipulative skill, and of doing it by teaching the very work that will be nearest to them in their normal daily life when they have left school.'

A Committee of this Association was appointed in 1903 at Southport 'to report upon the course of experimental, observational, and practical studies most suitable for elementary schools.' The Committee nominated several Sub-Committees, which have been actively employed in working out the details of a scheme. Individual members of the Committee have also been engaged on the problem, and have written papers and reports on some of its special aspects. In 1904, at the meeting of this Association held at Cambridge, I made some suggestions on workshop instruction which, I am glad to note, are now bearing fruit. In 1906 at York the Committee presented a report in which they indicated the character of the changes to be introduced into our schools with a view to make practical studies an essential part of the school curriculum. To this

Report were added valuable appendices, the results of the labours of some members of the Sub-Committees, dealing in detail with the methods of teaching arithmetic and mensuration very much on the lines suggested by Professor Perry at the Belfast Meeting in 1902, and also with nature-study in its relation to the general curriculum and with domestic work.

There are many satisfactory indications that the Board of Education are now moving in the direction indicated in the Committee's Reports, but they are moving slowly. Workshop exercises, nature study, and domestic science are now regarded as essential parts of the curriculum of our primary schools. Some of the prefatory memoranda to the Board's regulations are excellent. They breathe the true spirit of educational reform. In the preface to this year's Code it is gratifying to find a statement to the effect that the age for commencing handicraft instruction has been reduced from twelve to eleven. This somewhat belated concession will help to remove many difficulties. It is further stated in the same memorandum: 'The Board have under consideration the question of developing all forms of manual instruction in the lower classes of public elementary schools, and, in particular, of filling up the gap between the infant school, in which manual instruction is an essential part of the curriculum, and the upper classes, to which the teaching of hand-work is at present confined.' This is a welcome statement and full of encouragement, as promising to give effect to some of the recommendations of your Committee. But it does not go far enough. It leaves much to be yet done. The reference to manual training occurs in a Section of the memorandum headed 'Instruction in Special Subjects.' Why special subjects? What we ask for is that manual instruction shall be 'an essential part of the curriculum' in the elementary as it is in the infant schools; that it shall be closely associated with practical science teaching and with drawing and with other parts of the school curriculum. For many years I have urged that hand-work should be made the chief instrument of elementary education; that the brain should be developed by means of manual exercises; that practical studies should dominate the teaching. We are coming to understand that the attitude of passive receptivity in the pupil—a condition of mind too frequently welcomed by the teacher—should be discouraged, and that the lessons should be such as constantly call forth fresh energy. There is an increasing tendency to associate more closely the activity of the playground with that of the classroom. It is felt that the child's energy should be utilised in school, and not wholly dissipated in play. The true function of the playground is not the utilisation of unspent energy and exuberant spirits, but relaxation and recreation. The recognition of this fact will lead to far-reaching changes in school life. We shall see physical and mental energy jointly utilised in school, and not separately, as now, in lessons and in play.

If these general principles are sound it follows that much of the instruction now given in our schools must be closely associated with, and should be so organised as to arise incidentally out of, the pupils' practical work. This work should not be everywhere the same. It would be different after a certain age for boys and girls, different in urban and rural schools. It would vary in different parts of the country. The system of education should not be too strictly codified. Much should be left to the initiative of local authorities. But how varied soever may be the subjects and instruments of the instruction to be provided in our schools the essential feature of elementary education should be the practical studies, whether in connection with the work of the shop, the field, or the home.

Speaking roughly, the child's time would be about equally divided between practical manipulative work and the ordinary lessons in reading, writing, and reckoning. This, however, does not mean that what is known as the half-time system, by which the child spends half-time in school and half-time in the commercial shop, is to be commended. On the contrary, such an arrangement interferes with the discipline of school-work and in most instances over-exerts the child at an age when his strength should be carefully husbanded. Moreover, the shop-work cannot be correlated, as in the school it should be, with his ordinary lessons. Indeed, it is desirable that the instruction he receives in the three R's should have a bearing upon his practical work, and should be intimately associated with his surroundings and his everyday life. In our Report of 1906 it is stated that the 'faults inherent in our present system of elementary education would be 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 the Appendix to that Report it is shown how lessons in arithmetic should be founded on actual measuring and weighing, and co-ordinated with the teaching of experimental science. Among the many important recommendations of that Sub-Committee—one of the 'fundamental principles'—was that 'so far as possible all reasoning in arithmetic should be from the concrete to the abstract, and that pupils should learn by the manipulation of objects; and that all rules should represent results of experience.' In the Appendix dealing with nature-study it is stated: 'The experimental teaching in school is easily linked to the outdoor life of field and hedge-row with which the country children are familiar.' The Sub-Committee wisely condemns the working to any definite syllabus. 'A syllabus, they say, may be useful as a humble servant, but it is a very bad master.'

In my Presidential address to this Section last year I urged that in our elementary schools 'the child should receive less formal teaching, that opportunities for self-instruction through outdoor pursuits, manual exercises, and the free use of books should be increased; and that as far as possible the teacher should keep in view the process by which in infancy and in early life the child's intelligence is so rapidly and marvellously stimulated.'

To-day a report of considerable interest on the teaching of elementary experimental science will be considered. The Report has been drawn up by Mr. Heller, the Secretary of our Committee, with the assistance of the Sub-Committee appointed to consider this important branch of elementary education. The Report very properly refers to the successful efforts of Professor Armstrong during the last twenty years to improve the method of science teaching in our schools. It emphasises the contention of the Committee that the spirit of scientific inquiry must pervade our school teaching if effect is to be given to the educational reforms which we have recommended. In France, the necessity of some such fundamental change in the method of instruction is also recognised. At the recent meeting of the French Association for the Advancement of Science, Professor Paul Appell, of the Sorbonne, took as his subject, 'The teaching of the sciences and the formation of the scientific spirit.'

According to the short report of the meeting in the 'Times,' M. Appell defines the 'man of science' not as 'the man who knows,' but as a man who 'combines with his knowledge scientific activity; that is to say, a curiosity always alert, indefatigable patience, and, above all, initiative, and again initiative.' It is this spirit that we desire to see dominate the teachers and the teaching in our schools.

In connection with the main subject of our investigation there will be a discussion to-day from which we may expect to derive many valuable suggestions on 'Education in relation to rural life.' This aspect of elementary education has been hitherto too much neglected. No Acts of Parliament dealing with the tenure of land will effectually create a love of country life in the hearts of the people. Interest in agricultural pursuits must be fostered among our school children, and this can best be done by closely associating experimental science teaching with the daily work of the farmer and by encouraging initiative among the pupils in rural as in other schools.

It will be seen, therefore, that the Committee have been actively engaged during the past five years in preparing the ground for a complete reorganisation of our system of elementary education, and that their efforts have included the consideration of the changes to be introduced into the curriculum of urban and rural schools and of the studies most suitable to the pupils, whether boys or girls. The fundamental principle underlying the suggested reform is that work requiring manipulative skill shall be the dominant feature of the curriculum. Under the suggested scheme the school lessons will be essentially practical, and will be given in part in the open air or in the rooms to be equipped for experimental science and constructive work. The explanation of all practical processes will constitute the main subjects of the science teaching, which will be so organised as to stimulate accurate observation and correct reasoning. In the teaching of all subjects practice will precede theory, so that the explanation of any exercise will follow the ability to perform it. In connection with these practical pursuits will be provided lessons in arithmetic, geography, and composition, to consist largely of descriptive notes of the work in which the pupil is engaged. Apart from these subjects the pupil should have lessons in the history, and above all in the poetry, of his country, and in his duties to the State. The instruction will be such as to arouse activity, to satisfy curiosity, and to stimulate an intelligent interest in the subjects taught. In such a scheme, towards which we are slowly but surely working, there will be no 'special subjects,' no extra grants for supplemental teaching. The manual training—recently introduced into our schools—will become the 'corner stone' of our new educational building. The curriculum will be narrower than at present; it will embrace fewer subjects, but it will be one and undivided, and all its parts will fit into one another, so as give a single aim and unity of purpose to the teaching. The methods will be the same in all schools. There will be the same endeavour everywhere to arouse 'scientific acivity,' 'a curiosity always alert,' and, above all, initiative, self-reliance, and resourcefulness in the pupils. But the subjects of instruction—the instruments of education—may vary and will be adapted to local needs.

This great reform, which the Committee of this Section and many of the members by their individual efforts are endeavouring to promote, cannot be effected without further provision being made for the training of teachers nor without considerable improvements in the methods of instruction at present adopted in our training colleges. If our system of education is to be changed, the teachers must be competent to use the newly devised instruments. They must be equal to their task. The Sub-Committee in their report on experimental science very rightly point out: 'It is of little avail to advocate the teaching of a method or subject unless an adequate supply of teachers fully competent to handle the subject can be trained.' That supply does not yet exist. The teachers must not only be fully conversant with the method, but must possess an adequate knowledge of their subject. In these introductory remarks to the papers to be read to-day I do not propose to consider what should be the qualifications and special training of our future teachers. But it is certain that the qualifications and the training must be in many respects different from what they now are; and we may be sure that, as the qualifications of the teacher are strengthened, his status in the profession will be improved.

I trust that the new universities about to be created in Dublin and Belfast will be the means of providing a suitable training for the teachers in Irish schools. Let me take this opportunity of congratulating the people of Ireland on the prospect which the foundation of these universities will afford of securing for all classes of citizens in Ireland further opportunities for higher education. In facilitating the passage through Parliament of the Irish Universities Bill, I took some part, and I sincerely hope that a satisfactory arrangement may be made for enabling those who are training to become teachers in elementary schools to take full advantage of the wider learning and broader views of life which residence at a university offers. Dublin will before long enjoy the unique and exceptional privilege among the cities of Europe of being the seat of two teaching universities, and I am sure that all parties in Great Britain, divided as they may be politically and by religion, concur in felicitating Ireland on the advantages which these additional opportunities for higher education may bring to all her citizens.

The Committee appointed in 1903 are desirous of continuing their efforts in the directions which I have indicated. The work in which they are engaged is one of national importance. Year by year it is being more directly brought home to us that in every branch of public service, in every grade and variety of professional life, the prosperity and well-being of this country largely depend upon the early training of our citizens and upon the suitability of their studies to their future occupations. It is anticipated that the papers to be read at this year's meeting of the Section will prove a valuable contribution to the solution of the problem which has engaged, and continues to engage, the careful consideration of your Committee.

In presenting the following report of one of its Sub-Committees the Committee is glad to avail itself of the opportunity of placing on record the unique experience which Mr. Heller has had in organising and superintending the instruction in experimental work in elementary schools, first as an organising inspector under the London School Board (1894–97), and afterwards, since 1900, as head-organiser and inspector of science instruction for the Board of National Education, Ireland. The report has the advantage that all the recommendations that are brought forward in it are based on actual results of work carried on, not in a single school, but in a large number of schools both in England and Ireland.

Report of the Sub-Committee on Elementary Experimental Science.—Members: Professor H. E. ARMSTRONG, Mr. HELLER (*Secretary*), Dr. KIMMINS, *and* Professor SMITHELLS.

Twenty Years of Progress.

This branch of instruction in primary schools has been the subject of inquiry within recent years by two Committees of the Association. The fundamental principles that should guide the teaching of elementary experimental science were clearly enunciated in the 1889 and 1890 Reports of the Committee of Section B on the teaching of chemistry. The experience of the past fifteen years tends to emphasise rather than to modify the recommendations of those Reports. During this period a remarkable transformation has taken place in the teaching of elementary science in this country, traceable in its origin to the 1889 and 1890 Reports and to the indefatigable efforts of Professor Armstrong and other members of that Committee to achieve reform. In place of a large number of alternative specific subjects, none of them really fundamental in character, it is now insisted that there should be one general introductory course, indoctrinating that alphabet of scientific method and knowledge upon which the intelligent study of all specific sciences is based. The Reports directed attention to the overwhelming importance of method in instruction by insisting that mental training and the formation of accurate habits of observation, of work, of reasoning, and of description were at the early stage of education of far greater moment than the accumulation of facts or the ability to answer examination questions on these facts. The deliberate intention to achieve these ideals must lie behind all teaching of elementary science. To accomplish such ends it was found necessary to recommend a complete change in the methods of instruction commonly practised and in the attitude of the teacher towards his pupils and his subject. The 'results system' of the 'Science and Art Directory' and the Board of Education's 'Code' had, after twenty years, well-nigh killed the art of elementary teaching, the learning of rules and half-understood facts having become general. The method of experimental inquiry is the only natural method of gaining a knowledge of scientific facts but such a method is the very antithesis of the didactic method of instruction too generally in vogue.

The practical method of inquiry now known as 'heuristic' has been defined as 'carefully directed inquiry.' Instruction should take the form of the experimental solution of a series of problems arranged in rational sequence. The motive for the experiment must be the outcome of skilful teaching, in which the teacher has led his pupils from the known to the unknown and to a clear conception of the problem to be solved; the experiment should not be merely an occasional effort to substantiate one of the many facts that the teacher has told his class.

Teaching in which experimental results are to form the basis of reasoning and to be regarded as suggesting new problems should involve precision; the facts must at least be true or the method is obviously of no more value than those it is intended to supplant. Measurement may be the basis of experiments and quantitative thinking should always be encouraged.

The Reports referred to have profoundly influenced directly and indirectly the science teaching in secondary schools. Well-equipped laboratories have been provided in almost every good school and the attempt to give logical experimental instruction is at least professed. Test-tube work and the analysis of salts are for beginners a thing of the past, and the balance is made the basis of the first years of experimental work. During the *régime* of the inspection of 'Schools of Science' by the officials of the old Science and Art Department good constructive work was accomplished, and this period did much to set the standards of work since adopted in secondary schools generally.

In the primary schools great changes have also taken place; the higher grade schools of the larger urban education authorities are usually well equipped and a special teacher of experimental science is appointed to take charge of the laboratories. Increased provision has also been made in pupil-teacher centres and in training colleges for the teaching of experimental methods.

In many urban centres, from reasons of economy and because few of the ordinary teachers possessed an adequate acquaintance with apparatus and experimental methods, a special staff of peripatetic science demonstrators was appointed: these taught periodically in the schools of their district, usually carrying their apparatus about with them. The scheme of instruction followed was known as 'Mechanics' but embraced a superficial treatment of hydrostatics, the laws of force and motion, heat, chemistry and electricity. In some cases the individual ability of the demonstrator made the lessons useful and interesting, but the system was only adopted as a matter of expediency and the scheme of instruction has been far too comprehensive to lead young children to much real knowledge that could be applied to life later on. Under this system of peripatetic instructors little effort has been made or could be made to co-ordinate instruction in science with that in other subjects, such as composition, arithmetic, and drawing. Between the visits of the special instructor the class teacher was supposed to revise the lesson without the assistance of the apparatus that the former carried round with him: this revision was done in a half-hearted way and led to undesirable methods of memorising half-digested information.

It appears to be undesirable that the system of special peripatetic instructors should continue, except as a temporary expedient and until each school possesses a permanent and sufficiently qualified teacher of experimental science. The services of a staff of specialists should be employed in instructing the ordinary teachers, more especially in the methods of teaching and organisation. The rigid adherence to the class-teacher system met with in most primary schools should be abandoned and the best qualified teacher should be responsible for the instruction in several classes, if not for the whole school; it should be the business of the head teacher to ensure adequate co-ordination of instruction in drawing, composition, and arithmetic with that in science.

The Relation of Nature-Study and Observation Lessons to Experimental Science.

The 'Suggestions' of the Board of Education deal in detail with the aims and methods to be observed in nature-study, the advice therein given being substantially in agreement with our Report presented at the York Meeting. It is satisfactory to notice that the guiding principles which through the teaching of experimental physical science have been instilled into the minds of teachers are now recognised as applicable and desirable in instruction relating to natural objects and phenomena; at the same time it is to be feared that the present tendency to substitute in the higher standards of schools 'nature-study' for a systematic, logical, and progressive course of experimental physical science has grave dangers.

A very considerable amount of the 'object teaching' in the lower standards is of a highly artificial character, being in most cases educationally valueless. The disconnected series of lessons on subjects which come most easily to the teacher's hand—for example, a table, a chair, a pen, a piece of chalk—which has become traditional, results in little more than a 'laborious elucidation of the obvious.' It would seem to be essential that a broad outline of a scheme of object-studies should be prepared by the teacher for the year's work in advance and that these should be connected at least in short series. They should involve to a large extent a real examination of individual objects by the pupils themselves and should on no account be demonstration lessons in which the teacher holds a single specimen in his own hands. Good subjects for such lessons are those connected with plant-life, for it is easy to obtain sufficient objects at practically no cost. In the minority of cases where the pupils can be taken out of doors under the charge of the teacher, real nature-lessons can be given; but in the majority, where the conditions of school work render such outdoor lessons an impossibility, much useful observation may be encouraged by mentioning the subject of the next lesson several days beforehand and by suggesting a few simple and definite inquiries. The lessons in the spring and summer months will be mainly in connection with natural objects, but in the winter months it will be difficult to obtain an adequate supply of objects for examination by the pupils. This period might be usefully occupied in lessons introductory to the work of the higher standards; the nature and uses of water, air, and food-materials form perhaps the most useful and interesting subjects. The lessons on water should involve the consideration of its sources, the work done by a stream, a river, and the sea, the change of water into ice and steam, the evaporation of water, the presence of its vapour in the atmosphere and the formation of cloud; the dissolving properties of water, its uses as a food and the large amount of water present in nearly all food-materials. The lessons on air might include some very simple experiments to show its reality and the pressure it exerts, leading to some first ideas as to its weight when hot and cold, the effects of heat upon it and its relation to burning and breathing. A few of the typical foodstuffs, such as eggs, flour, and sugar, might also be considered, with the object of showing that they are all combustible and contain carbon and a considerable quantity of water. Such a course of illustrated lessons in Standards II. and III. would do much to ease the difficulty of more systematic work in higher standards.

It is needless to say that the teacher who is to give the first ideas on these subjects to young children must be at least as well qualified as the teacher of more advanced work in the higher classes of the school. A more systematic and connected treatment will commence about Standard IV. and must of necessity begin with careful lessons in the measurement of size and weight.

In the endeavour to suggest a better correlation between instruction in physical and biological science, it must not be assumed that the

Committee fail to realise the great importance of the latter; the neglect of the study of outdoor life that huge classes and the methods of the 'results system' have engendered is to be deplored and in a previous Report the Committee have strongly advocated the employment of more scientific methods of instruction in this branch. English nature-study is largely based upon the writings and methods of American teachers, and the wave of enthusiasm which has spread from that country has brought together with much which is admirable much which is unsound and superficial. The neglect of experimental methods of inquiry in the teaching of physical science is one of the weakest points in the curricula of America's schools and in consequence their school nature-study has suffered. At any rate it should not be forgotten that Nature is concerned with dead as well as with living matter, and that a knowledge of the transformations of the former is essential to the study of the latter.

In the lower standards the degenerate 'object-lesson,' which more often than not amounts to little more than a didactic information-lesson, should give place to *real* study and observation of plant-life and the more obvious natural phenomena; before any detailed study of the conditions of plant-growth can be attempted with success a systematic experimental study of the simplest physical and chemical changes is necessary.

If science teaching is to achieve its full effect in training the reasoning powers and in the formation of accurate habits, it must involve the experimental solution of problems; as an instrument for exemplifying the experimental method of inquiry, physical science has many obvious advantages beyond those offered by a study of biological subjects; a study of such simple physical subjects as the nature of air, the effects of heat on matter, fluid pressure, the composition of the atmosphere and the effect of plant and animal life upon it, would seem to be fundamental to any intelligent study of plant growth and should certainly precede it; in the study of plant-life the conditions of experiment are so complex that the experimental method of inquiry can only be followed to a very limited extent in elementary schools.

The enthusiastic teacher who has made nature-study his hobby will rise superior to syllabuses and programmes and should be given a free hand; the average teacher, however, finds a carefully drawn and detailed syllabus of work helpful. For such teachers it is difficult at present to provide a scheme of biological studies that will ensure regular and progressive instruction. In physical science, the difficulty of preparing graduated syllabuses is not so great; some suggestions for experimental courses in different types of elementary schools are appended to this Report.

In deciding what practical work of an exact kind is most suitable for individual pupils in the upper standards of an elementary school we feel that by skilful teaching of experimental science better training may be given than by the conventional methods of nature-study and that it is more easy to obtain a supply of competent teachers in the former than in the latter branch. Further that much will be lost if the pupil leave the primary school without a knowledge of those fundamental facts necessary to the intelligent understanding of the common phenomena of daily life; he should at least be equipped with that substratum of knowledge of physical science which is necessary to the continued study of any branch of science, whether technical, agricultural, or domestic.

The 'Suggestions' of the Board of Education in reference to instruction in elementary physical science appear to be meagre and inadequate when contrasted with those in reference to nature-study; the scheme of work outlined by the Board is similar in subject-matter and scope to that suggested in the Reports of the Committee of Section B referred to above. The large amount of experience which has been gained during the past fifteen years in the working of this scheme indicates that it would be undesirable to effect many radical changes in it. The subject-matter included can be adequately taught during the last four years of the school curriculum, assuming that the first year's work is undertaken by pupils between the ages of eleven and twelve.

Training of Teachers.

It is of little avail to advocate the teaching of a method or subject unless an adequate supply of teachers fully competent to handle the subject can be trained. A training in the methods of experimental physical science although not easy has already been undertaken with some degree of success in many parts of the kingdom, but with a few brilliant exceptions comparatively little has been achieved in the training of teachers competent to direct nature-study; such training presupposes a knowledge of experimental method and a taste for and considerable knowlege of natural history. Under existing conditions it is easier to train teachers of physical science than it is to secure teachers competent to deal with the complex issues involved in the study of living objects.

Until recently, the training in science that teachers have received has done very little to equip them for their work in schools, and it is cause for congratulation that improvement is taking place in the character of the instruction given in the training colleges. It is not sufficient that the teacher should leave the college with a schoolboy's knowledge of science. However little he knows, he must have a teaching grasp of that little and have fully realised the aims and ideals to be kept before him. Instruction in the training colleges should keep the teaching idea continually in the minds of the students. The tendency to teach specific subjects of science in the training college should be discouraged. This is the function of the university or technical school; the business of the training college is primarily to show the future teacher the methods of his work. It is essential that students entering the training college should be fully familiar with the subject-matter of introductory courses in physical science. This condition is fulfilled where a student has attended a pupil teachers' centre or a secondary school. A large bulk of first-rate teaching material is to be found, however, in the existing teachers who have been engaged at their professional work for several years but have had no opportunity of being trained in scientific method. For these some provision must be made and there is ample experience to show that short practical courses under competent instructors have excellent and lasting effects. To conduct such classes of teachers it is necessary to secure instructors of special experience: they must have superadded to a good knowledge of science a very considerable teaching experience and should be familiar with the conditions of work in the schools concerned. For such classes sufficient apparatus must be provided, if possible, to enable the teachers to work independently; the chief purpose would be to illustrate the methods of instruction and to inculcate the proper attitude of mind in the teacher.

The course would be best divided into two parts, each of not less than a hundred hours, of laboratory instruction. Experience shows that students who have attended special classes or training colleges often fail to obtain a sufficient grip of the subject to enable them to teach effectively after the first course of lessons; a second revision course is of great value to these, especially if the teacher in the meantime make an honest attempt to teach the subject in school.

Organisation of Practical Work in the School.

Where the school is provided with a laboratory, it is desirable that one teacher should be responsible for its care and for the instruction that is given within it; if it is necessary to employ a second science teacher, he should act as an assistant to the responsible science teacher. A balance and other apparatus should be provided if possible for every two pupils in the laboratory. In designing a science work-room, it is neither necessary nor desirable to provide elaborate furniture. Strong tables fitted, if possible, with gas and plenty of floor-space are all that is really needed. A separate lecture-room is unnecessary, but a demonstration table and a few forms should be placed in the laboratory. It is undesirable to provide storage accommodation for individual pupils; cupboards under the tables should be designed for the purpose of general storage. There should be no shelving on the tables and two or three large sinks on the walls of the room are all that would be required.

In comparatively few cases, however, has the primary school a special room for the teaching of experimental science at its disposal; but in the majority of cases, where no such room or equipment is available, the individual practical work of the pupils cannot be carried out simultaneously. The few simple pieces of apparatus necessary for the leading experiment or experiments of the week's work should be kept upon a table in the class-room, or upon a narrow shelf hinged to the wall throughout the day, and pupils should be sent out singly or in pairs from time to time at the discretion of the teacher during any periods in which no class instruction is taking place, to repeat experiments which have already been carefully performed before the whole class and thoroughly explained. An equipment of value about 10*l*., in addition to a good strong table and storage accommodation, will enable a very considerable amount of practical work to be accomplished.

The minimum time necessary is one and a half to two hours per week, exclusive of the time devoted to the writing of notes, which may form a considerable part of the teaching of English composition in the school.

The teacher's demonstration lesson, in which he breaks new ground, should be of about one hour's duration. In this lesson, having led his class to an appreciation of the problem to be solved and having obtained from its members suggestions as to the mode of solution, the experiment will be performed, possibly with the assistance of some of the pupils, the results will be recorded and between this and the revision lesson later in the week or even in the following week the experiment, if suitable, will be repeated by the pupils working in pairs at odd times during the progress of other lessons. There are many suitable periods for such work and the ten or twenty minutes that a pupil keenly interested may spend at an accurate experiment will not be wasted nor will an appreciable interruption of other studies occur. Much successful work from this plan has been accomplished but, like any other kind of teaching, to be effective it requires an enthusiastic teacher who will take the trouble to organise it regularly.

In any school where the discipline is sound such individual work causes no interruption after the novelty of the first few lessons has worn off. All the experimental results obtained should be recorded and tabulated in a Log Book, in which the teacher also enters his results obtained at the demonstration lesson. No conclusions or generalisations should be drawn until a number of pupils have repeated the experiment and recorded the results. The teacher should then make these results the basis of his next lesson, endeavouring to trace the reason for the want of agreement of any particular result with the rest; conclusions should then be drawn, so far as possible, by the class, and the whole piece of work reviewed and suggestions made as to the method of writing an account of the work which has been done. It is necessary at first for the teacher to summarise on the blackboard the various points in order with which the composition should deal, but anything in the way of dictation or transcription is valueless. The compositions must represent the children's thoughts in their own words. The experiments which the pupils repeat individually should, as a rule, be those that yield a definite quantitive result; there is little to be gained by repeating individually merely qualitative effects.

Preparation of Lessons.

In a subject in which the methods of instruction are of greater importance than the intrinsic value of the information conveyed, the preparation of careful teaching notes is an essential element in success. It is impossible that science teaching can be fully effective unless careful consideration of every lesson is given beforehand. As year by year the teacher acquires increased experience, the amount of time that he will find it necessary to devote to the preparation of his lessons will diminish, but the more skilful he becomes the more will he appreciate the necessity for thought in his teaching. In the preparation of lessons he must consider carefully how he is to lead from what has been learned already to the subject-matter of the new lesson. Before suggesting any experiment he must make it absolutely clear why it is to be performed; the problem to be solved should be kept prominently in the minds of the pupils throughout the lesson. He must, further, consider all the difficulties the pupils are likely to meet in acquiring new ideas, and, finally, lay considerable emphasis upon the application of the results of the lesson to daily experience. But notes of lessons are not popular with teachers. The reason is not far to seek. In training colleges students often have been taught to write highly elaborate and highly artificial notes upon extremely simple subject-matter. The only useful notes are those which will help the teacher in his teaching; a few short sentences will usually be sufficient to indicate the train of ideas he intends to follow. Elaborate columns of heads, matter, and method have probably done at least as much harm as good.

In our General Report last year the following reference was made to the special importance of the teaching of experimental method in girls' schools:—

'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 course 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.'

There can be little doubt that at present boys exhibit more initiative than girls in the general work of the standards; girls appear to be more prone to work by rule of thumb. Without attempting to discuss the reasons for this characteristic, the fact remains that domestic duties call for more initiative, more executive ability, more power of organisation, and more common-sense, than do the ordinary vocations that boys follow on leaving school. The woman in the home is continually confronted with new problems the solution of which demands trained intelligence and a habit of thought. A training in the methods of experimental inquiry would appear to be the most direct means of creating the thinking habit, and if the subject-matter of inquiry chiefly relate to the phenomena and materials of home life such teaching should do much to render more rational the management of the home. Experiments made during the past three years in two large schools in Dublin and Belfast, in each of which five hundred boys and girls have been taught by the same instructor, tend to show no material difference between boys and girls in reasoning or manipulative ability after the first arithmetical difficulties have been overcome; we believe that the reforms in the teaching of arithmetic suggested in our last Report, accompanied by accurate experimenting, would do much to abolish the love of rules and recipes so often noticed in the higher classes of girls' schools. There is little reason to advocate different courses of instruction for boys' and girls' schools; the explanation of the common phenomena of daily life are of equal importance to both, although it may be advisable to consider popular prejudice and make the boys' programme look a little less domestic than that of the girls.

The character of the instruction in both boys' and girls' schools requires to be far less academic than heretofore; there must be more deliberate purpose of training to think and reason in terms of everyday life. A lesson without some application to common experience should, in the primary school, be regarded with suspicion.

Inspection.

The aims and methods we have advocated obviously demand much enthusiasm, intelligence, and skill on the part of the teacher. To appreciate such effort, the inspector must be at least as familiar with the subject-matter and the proper modes of its presentment as the teacher himself. Nothing takes the heart out of a teacher so quickly as a want of appreciation of really earnest work. In assessing the value of such work the inspector should ascertain that a carefully thought out scheme of work has been regularly and progressively followed ; an examination of the pupils' note-books recording the year's work, supplemented by some general oral questions and the carrying out of practical exercises by a selected number of pupils, should afford him all the information that is necessary. If the class does not show an intelligent understanding of the purpose for which experiments were performed, it is desirable to examine the character of the teacher's preparation of lessons.

The Committee desire to direct attention to the following conclusions and recommendations :—

(1) The recommendations of the Committee of Section B on 'The Teaching of Chemistry,' in reference to the subject-matter and methods of instruction should be followed in giving instruction in 'Elementary Physical Science.'

(2) They do not consider the system of peripatetic science instructors satisfactory, except as a temporary expedient.

(3) Every primary school should be provided with a special work-room simply furnished, in which many forms of practical study could be followed—*e.g.*, manual instruction, drawing and elementary science for boys, and cookery, laundry, drawing, and elementary science for girls.

(4) That while fully appreciating the value of studies of natural objects and changes they do not consider that 'nature-study,' as conducted under the conditions of work prevailing in the average primary school, provides *by itself* a satisfactory substitute in the higher standards for formal and systematic instruction in elementary experimental work in physical science.

(5) Much of the present object-teaching in primary schools is practically valueless ; throughout the standards some study of natural objects is desirable.

(6) In the training colleges more attention should be paid to aims and methods of instruction in elementary science.

(7) Ample provision should be made for classes of a pedagogic character, in which existing teachers may become acquainted or increase their acquaintance with methods of experimental inquiry.

(8) Accurate practical work by individual pupils is essential if the teaching of experimental science is to achieve its full educational effects.

(9) Where practical work by all the members of a class simultaneously is impossible, much useful practical work may be done by a few working at a time.

(10) They regard the teaching of methods of experimental inquiry as being of even greater importance to girls than to boys, in that it provides a training of special importance in domestic management.

(11) The teaching of domestic art should be much more closely

co-ordinated with the teaching of domestic science and the former should be so taught as to provide an intellectual as well as a manual training.

(12) It is important that inspectors of schools should possess an adequate knowledge of the subject-matter and methods of instruction in elementary science.

APPENDIX A.

Syllabus of Work in Elementary Experimental Science.

NOTE.—It is assumed that in their arithmetic lessons the pupils have acquired skill in the measurement of lengths and areas and have through these exercises obtained a real knowledge of the manipulation of numbers in the decimal system not involving the use of more than two digits after the decimal point.

Syllabus for Boys' Schools, First Year (about 11 *to* 12 *years of age).*

The measurement of volume of a rectangular block of wood. The reason for selecting the cube as the unit for measuring volume and capacity; explanation of the rule for calculating volume of a rectangular solid—a means of counting the number of unit cubes that will build up the solid.

Cut out of turnip, soap, clay, &c., cubes of one inch and one centimetre edge. To make a hollow cube of cardboard of one decimetre edge, the volume of which is the litre, containing 1,000 cubic centimetres. Mould some putty or plasticine into rectangular shape, and determine its volume by measurement; distort it, and lead class to see it still occupies the same amount of space, and may still be measured in rectangular units.

The volume of rectangular blocks of wood (including cubes) in cubic inches and cubic centimetres; the number of cubic centimetres in a cubic inch.

The graduated cylinder; the fluid ounce and measuring glass; the number of cubic centimetres in a fluid ounce; fill a water-tight rectangular box with water, and pour into graduated cylinder; compare volume by direct measurement and by graduated cylinder; the limits of accuracy in using the graduated cylinder. Volume of small bodies by displacement in graduated cylinder.

The burette—a more finely divided graduated cylinder. Volume of small bodies such as pencils, glass rod, nails, by displacement in burette. The pipette—its method of use. Direct measurement of capacity of a bottle by burette and pipette.

First notions of force and weight—the measurement of a pull or push; the force of gravity very simply treated. Equal weights defined as those that stretch a spiral spring or an elastic cord to an equal extent; construction of a series of bags of sand or shot of equal weight.

Experiments with a simple lever or seesaw; equal weights balance at equal distances from the turning edge.

British and metric units of weight and capacity; the gallon and its subdivisions; a gallon of water weighs ten pounds. To weigh cubes of different kinds of wood on the seesaw.

The balance, adjustment and use; weight of cubes of wood, determined to $\frac{1}{100}$ gram.

Weight of volumes of water (30, 40, 50 c.c., &c.), measured from burette and pipette, leading to the fact that one cubic centimetre of water weighs one gram. Repeat these experiments with hot and lukewarm water.

Weigh volumes of milk, spirit, brine, mercury, &c., measured from burette, and to calculate the weight of 1 c.c. of each.

Find the weight of 1 c.c. of milk, skimmed milk, cream, and mixtures of fresh milk and water. Measurement of amount of cream in milk by allowing 100 c.c. of fresh milk to stand for some hours in graduated cylinder.

Heavy and light materials; to compare heaviness of materials we must find the weight of equal volumes of each. By finding the weight of one cubic centimetre of each substance, we can find their relative weight. Necessity for comparing all materials with one standard substance. The reason for selecting water as this standard. The simplicity in the metric system of the connection between weight and volume of water.

Tabulation of results of weight of 1 c.c. of all materials previously measured. Weight of unit volume of a substance a very general method of determining its quality or the amount of adulteration.

'Water finds its own level'; experiments to explain this statement. Columns of liquid balanced in U-tube; equality of level in tubes of equal and unequal bore. The flow of water in pipes of a town supply.

Revision of the relative weights of 1 c.c. of water and of mercury, showing that mercury is about $13\frac{1}{2}$ times as heavy as water. Columns of water balanced against columns of mercury in U-tube, showing that the water column is always about $13\frac{1}{2}$ times the length of mercury column; deduce the law of the U-tube, and by it confirm the results previously obtained for weight of 1 c.c. of brine and spirit.

Simple experiments and illustrations to show the reality of air; water does not fill a tumbler of air inverted in a vessel of water; air necessary to burning of a fire and for breathing; the blacksmith's bellows and the bicycle pump. Solids, liquids, and gases. Air, an invisible gas like coal-gas, but having no smell, not so easily recognised. Steam also an invisible gas. Inflate an indiarubber balloon; pump up a bicycle tyre; pass air through water, and collect it by displacing water from a jar inverted in water. Fill a jar inverted in water by sucking the air out by means of a tube.

In order to weigh air we must be able to expel it from a vessel. Show that it may be expelled (*a*) by an exhaust pump, (*b*) by boiling water in the flask, (*c*) by expansion by heat. Collect the air driven out of a flask by boiling water in the flask, and thus show that all the air is expelled. Open a partially exhausted flask under water.

Weigh a flask first full of hot air, and then full of cold air; explain why hot air rises, and its application to natural ventilation. Simple experiments to show that air exerts a pressure on bodies; experiments with tubes of water and mercury to show that there is a limit to the pressure of the atmosphere.

The U-tube or siphon barometer; the straight tube barometer. Changes in height of mercury in barometer compared with changes in the weather. Daily observations of barometer, kind of day, winds, direction, and strength; height of sun at midday.

NOTE.—It is not desirable that the term 'density' should be used in the first year's work; all results should be recorded as the weight of 1 cubic centimetre in grams.

Second Year (about 12 to 13 years of age).

Simple experiments with a lever having its fixed point (fulcrum) at one end to show connection between the force (power) and the load it can raise. A small force can raise a heavy load, but the small force works through a greater distance than the load is raised. Familiar applications of the lever—crowbar, poker, scissors, fire tongs, weighing machines.

Determine the capacity of a bottle by weighing the water it will hold; find the weight of other liquids—milk, mixtures of milk and water, skimmed milk and cream that fill the same bottle, and hence calculate the weight of unit volumes of these liquids. Weight of unit volume a means of testing quality or adulteration of materals. Reasons why the authorities are so particular as to the milk-supply; milk the only food of very young children and any removal of cream or addition of water would seriously affect nutrition.

Weight of unit volume of hot water. Revision of weight of air. Construction of simple air and water pump.

Determine the weight of one cubic centimetre of air by (*a*) partially exhausting flask with an air pump, (*b*) by boiling a small quantity of water in the flask. Definition of density as the weight of unit volume of a substance.

Floating bodies; reference to earlier experiments with cubes of wood, some of which float and others sink, to show that bodies heavier than water sink in water and others float; an egg suspended midway in a brine solution is neither heavier nor lighter than the brine; calculation of the weight of one cubic centimetre of the egg.

Experiments to show that a floating body displaces its own weight of water, and to find the fraction of its volume immersed in water. Construction of hydrometer to measure dilution of milk with water.

Application of the laws of floating bodies to ships; why iron ships float.

Familiar examples of apparent loss of weight of bodies in water; refer to carriage of rocks and stones by rivers; the diver works under water loaded with lead; experiments with bodies of known volumes weighed in air and water; discovery of law of Archimedes; increase in weight of a vessel of water when a body is suspended in it from an external support.

Use of the law of Archimides for finding the volume of irregular bodies heavier than water; calculation of the weight of one cubic centimetre of these bodies.

Show that this method of finding volume, since it depends on the use of the balance only, is more accurate than any previously employed.

General effects of heat on animal and vegetable matter; wood and coal heated in hard glass tubes give off inflammable gases which burn in air. The char of carbon left in the tube will not burn until heated *in air*; air evidently necessary to charcoal burning. When it is completely burnt a light mineral ash is left. Carefully dry some finely divided animal and vegetable matter and determine percentage of water. The water in foods does not provide nourishment; the combustion of foods produces heat.

Notice effects of strongly heating weighed quantities of sand, granite, limestone, iron, copper, magnesium, &c. Some do not change, some lose weight, and some gain weight.

Expansion of solids, liquids, and gases shown qualitatively. Applications of expansion by heat to method of fixing metal tyres on wheels, riveting, circulation of hot water, ocean currents, winds, draughts, and ventilation.

Hotness or temperature measured by expansion of liquids. Distinction between *heat*, which is energy and possesses the power of doing work and producing change, and *temperature or hotness*, which is the intensity of heat; analogy with quantity and pressure of water or gas. Definitions of *unit of temperature* (degree Centigrade) and *unit of heat* (calorie or gram degree Centigrade unit). Comparison of times taken to raise large and small quantities of water to the same temperature by the same source of heat. Amount of heat depends on quantity of material heated.

Construction of spirit thermometer; graduation of thermometer for household purposes. The effect of large masses of warm water round the coast of British Islands on its climate.

The freezing of water; ice always formed at the surface; ice will float; find density of ice by making a mixture of spirit and water in which a lump of ice remains suspended; find the weight of 1 c.c. of the mixture. The reason why water freezes at the surface; economic importance of the fact. Applications of the increase of volume of water when freezing to bursting of water pipes, to the breaking up of the soil in winter, to the spliting of rocks, &c.

The boiling of water; steam and water vapour both invisible gases; the nature of cloud, dew, frost, rain, snow. The boiling-point of water varies slightly with the ordinary changes in barometer, and very considerably at great altitudes or depths.

Determine whether a number of familiar substances are soluble, partially soluble, or insoluble in water. Filtration as a means of separating soluble from insoluble bodies. Distinction between dissolving and melting, as illustrated by the solution of sugar in water and the melting of sugar by heat.

Determination of the solubility, *i.e.*, the weight of solid dissolved in a given weight (or volume) of its solution—of familiar substances, salt, soda, sugar, tea, lime. Food materials must be rendered soluble before they can pass into the blood stream and nourish the body. Small amount of solid nutritive material in most beverages.

Distillation of liquids—a double process of boiling and condensation. The large amount of heat absorbed in converting water into steam. The heating power of steam. Purification of a liquid by distillation. Production of alcohol by distilling a fermented sugar solution.

Burning of a candle in air confined over water; the nature of the residual 'inactive air.' Moisture and a gas which turns lime-water milky produced by the burning candle. A candle will not burn in breathed air.

The rusting of iron. Iron moistened and exposed to the air rusts and increases in weight, but iron will not rust in boiled water. Iron rusting in a jar of air causes the disappearance of about one-fifth of the whole. The residual gas is 'inactive,' but does not affect lime-water. The same 'active' part of air is concerned in burning, rusting of iron, and in breathing.

Third Year (*about* 13 *to* 14 *years of age*).

Experiments with siphon to see how rate of flow varies with difference in level of the liquids. Uses of the siphon for emptying tanks or reservoirs; draw curve connecting time of flow with average difference in level during flow.

The volume of small irregular bodies found by weighing the water displaced from a bottle by them. Relative density of mercury, sand, shot, &c (The solid should be weighed independently of the bottle so that pupils may see the water displaced.)

Extension of the principle of Archimedes to liquids other than water; a body of known volume weighed in a liquid of known density to show that apparent loss of weight is the weight of the liquid displaced.

Modes of transference of heat; simple experiments to illustrate conduction, convection, and radiation, and the application of these to warming, clothing, &c. The radiant heat of the sun.

Expansion of a metal tube; comparison of expansion of water and alcohol under same conditions; applications of expansion of solids and liquids to experiences of daily life.

Determination of expansion of unit volume of air when raised 1° C. Repeat experiment if possible with coal-gas. Application of expansion of gases to ventilation, explosives, winds, &c.

The unit of heat; calculation of heat lost and gained by quantities of water when cooled or warmed. Heat energy like matter indestructible. The heat absorbed by a copper vessel in which hot and could water are mixed.

Heat-capacity of metals; the high heat-capacity of water compared with other substances; the great importance of this fact in reference to climate and the retention of its heat by the human body; heating by hot water.

Comparison of amount of evaporation from a beaker of water on a fine and wet day. Cooling effect of evaporation; the evaporation of perspiration on the skin, and from the leaves of plants. Life possible in temperatures much above maximum safe body temperature.

Chemistry of the atmosphere. Air passed over heated copper examined.

Air passed over heated phosphorus, sulphur, and carbon; lead when heated first converted into a yellow scale (litharge), then into a red scale (red lead).

Composition of the air by volume, by burning phosphorus in a dry tube or flask, and by the rusting of iron.

Preparation of the 'active part' of air from red lead, and from a mixture of potassic chlorate and manganese dioxide. Sulphur, carbon, and phosphorus burnt in 'active air' produce acids, hence the name oxygen.

Oxygen passed over heated carbon; properties of carbonic acid gas.

Air synthesised by mixing oxygen with residual air from the burning of phosphorus and the rusting of iron. Combustion due to chemical union which produces heat; decomposition of substances by heat. Effect of animal and vegetable life on the air.

The Bunsen burner and gas stove; candle and coal-gas flame compared; coal gas if mixed with air or oxygen is explosive. Lamps and burning oils; precautions to be observed in using oil lamps; the paraffin oil pressure blow-lamp.

The nature and functions of breathing; simple experiments to show that a candle will not burn in breathed air; count the number of respirations per minute under different conditions; length of time one can hold breath without discomfort; breathe rapidly, and then see how long one can hold breath. The moisture, carbonic acid gas, and organic matter in breathed air.

Fourth Year (*about* 14 *or* 15 *years of age*).

The volume of a gas changed by pressure; Boyle's law; the U-gauge for measuring pressures of air and water.

Change of state; simple experiments to show that heat is absorbed when solids are converted into liquids and when liquids are converted into gases; determination of latent heat of water, *i.e.*, the number of heat units necessary to melt a gram of ice.

Latent heat of steam, *i.e.*, the number of heat units necessary to convert a gram of boiling water into steam. Applications of latent heat to evaporation; steam as a motive power, slow formation of ice, steam scalds, damp clothing, &c.

Chalk, limestone, and lime; the action of water upon these; slaked lime a compound of lime and water. The conversion of chalk into lime in the lime-kiln; the loss of weight and production of 'chalk gas' during the change.

The action of acids on chalk and lime; weight and volume of 'chalk gas' produced from a gram of chalk. Identity of 'chalk gas' with carbonic acid gas previously studied.

The synthesis of chalk from lime and 'chalk gas'; the action of carbonic acid gas on lime-water, producing a 'hard water' containing a soluble form of chalk. The comparison of the hardness of waters by means of soap solution.

Action of acids on metals. Preparation of 'inflammable air.' 'Inflammable air' burns producing water, hence name hydrogen.

Decomposition of water by passing steam over heated iron; reduction of oxides by hydrogen; composition of water; properties of natural waters. Dangers of impure water and means of rendering it safe for drinking purposes.

Acids and alkalis; alkalis in common use—ammonia, potash, and soda—in the caustic and carbonated conditions. Interaction of acids and alkalis, producing neutral substances. Exact neutralisation of acids by alkali, and *vice versa*, using indicating colouring matters, litmus, and methyl orange.

Alkalis render fats soluble, producing soaps. Preparation of a sample of soap from fat and caustic soda. Caustic soda produced by removing the carbonic acid gas from washing soda by means of lime.

The necessity for cleanliness; the dangers of dirt; germs and their influence on daily life; conditions favourable to germ life—darkness, dirt, warmth, and moisture. Of what dirt consists; greasy dirt requires alkalis (soda, ammonia) for its removal.

The nature of germs; minute vegetable organisms which multiply with great rapidity, and chiefly concerned in breaking up complex organic substances by oxidation. Germs of disease communicated from person to person by contact, by the breath; water and milk specially liable to contamination; fresh air, cleanliness, and sunlight destructive to germ life.

The elements entering into the composition of the human body—carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, calcium, sodium, and small traces of others. These, especially carbon, oxygen, hydrogen, and nitrogen, are continually used up and excreted, and must be renewed in form of food. Importance of mixed diet.

Food the fuel of the body; a slow or wet burning of food which maintains temperature of body above that of its surroundings. The chief types of food-material—fat, lean, sugar, and starch; these required for all the important functions of the body.

General structure and functions of the digestive system; foods must be rendered soluble before they can enter the blood stream and nourish the body.

Respiration and circulation of the blood. The functions of the heart, lungs, and skin.

Putrefaction and decay. The general influence of bacteria (germs) on daily life; simple experiments on sterilisation.

APPENDIX B.

Syllabus for Girls' Schools. Domestic Science.

First Year (about 11 *to* 12 *years of age).*

Same as for boys.

Second Year (about 12 *to* 13 *years of age).*

Find the weight and volume (either by direct measurement or by displacement of water) of pieces of wood, glass, slate pencils, cork, paraffin wax, shot, &c. Tabulate the results, and calculate the weight of 1 c.c. of each of these, and note which are lighter than water and heavier than water; throw them all into a vessel of water, and notice that those heavier than water sink and those lighter than water float.

Weight of water displaced by a floating body. Determine the water displaced by weighed pieces of wood, cork, or wax floating in an 'overflow jar,' leading to the discovery that a floating body displaces a quantity of water equal to itself in weight. Float a test-tube loaded with shot or sand in a graduated cylinder of water; compare weight of loaded tube and weight of water displaced. With a test-tube, cork, and glass tube construct a milk-float that will test whether milk has been diluted with water.

Find the weight and volume (by 'overflow jar') of a fresh egg, and hence weight of 1 c.c. of the egg. Make a strong brine solution, and notice that the egg will float in it; carefully dilute the brine with water until the egg remains suspended in the liquid; find the weight of 1 c.c. of the brine solution; compare this with the weight of 1 c.c. of the egg. By making a large quantity of brine in which a fresh egg will neither float nor sink we have a ready test for the freshness of eggs.

Burn on the lid of a crucible some finely divided animal and vegetable material, *e.g.*, lean and fat meat, cheese, bread, potato, and notice carefully all changes that occur. Dry in an evaporating-dish placed in a cool oven or over a water-bath some of the above substances, and determine the amount of water lost. Strongly heat some splinters of wood in a hard glass test-tube until no further change occurs. Show that the sticks of charcoal will burn when heated in the open air.

Completely dry some of the food-materials mentioned above, and strongly heat weighed quantities until all the black charcoal is burnt away and unburnable ash only is left. Notice that on burning animal matter there is a more pungent smell than when sugar or potato or starch is burnt. Lead pupils to see that a food with a high percentage of water in it (like turnip) cannot be as nourishing as one with little water in it (like cheese).

Show that heat causes a metal bar or stretched wire to become longer; the expansion of solids by heat is very slight, but sufficient to cause the cracking of glass vessels and lamp-chimneys, owing to unequal expansion of different parts. Refer to cracking of iron plates of a stove, to tie-bars in old houses, to railway lines, &c.

Show that liquids when heated expand more readily than solids, and that different liquids do not expand to the same amount. Weigh a bottle full of cold water and full of hot water. Hot water is lighter than cold water, and will rise above it. Show 'convection' currents in a beaker of water when heated. Refer to ocean currents and the circulation of hot water in a house system.

Construct a spirit thermometer, and graduate it to show temperatures of melting ice (0° C. or 32° F.), of a living room (about 60° F.), of the human body (98° F.), of a hot bath (not higher than 100° F.). The Centigrade and Fahrenheit methods of graduating the thermometer.

The mercury thermometer; the boiling-point and freezing-point of water. The thermometer an instrument to measure temperature or hotness. First notions of heat as distinct from temperature. The measurement of amount of heat depends upon at least two quantities—the amount of substance heated and the temperature to which it is heated.

The doctor's thermometer for measuring the temperature of the human body; constructed so that it still indicates the body temperature when removed from the mouth of the patient; method of using and cleansing; temperature of body in sickness and in health.

Ice floats on water; water when frozen must therefore expand; make a mixture of spirit and water in which ice remains suspended; find the weight of 1 c.c. of the mixture, and hence weight of 1 c.c. of ice. Refer to bursting of water-pipes by ice, and explain why ice is always found at the surface, and the importance of this fact.

Air expands much more readily than solids or liquids when heated. Heat a Florence flask in hot water, and find how much 1 c.c. of air expands when made 1° C. hotter. Weigh a flask first full of cold air, then of hot air. Hot air is lighter than cold air. Show the air currents above a flame in a hot room and up a chimney. Refer to winds, draughts. Show effect of a strong draught on the burning of a fire.

Burning and breathing both make the air hot and poisonous, and unfit to be breathed again. Natural and artificial means of ventilating a room. Necessity for fresh air and sunlight.

Determination of melting-points of butter, paraffin wax, or beeswax, and boiling-point of water, brine, spirit.

Evaporation or drying—the slow change of liquid into gas or vapour. Evidence that heat is absorbed during drying; clothes dry quickly on a windy day; good and bad drying days; compare with barometer readings. Presence of water vapour in the air. Evaporation of perspiration on the skin, and its cooling effect in hot weather.

Textile fabrics (especially woollens) have power of absorbing water vapour from the air. Weigh roll of dry flannel, and again weigh after exposure to air for a couple of days. Make daily weighings of a bag of seaweed, also observations of thermometer, barometer, and the kind of day.

Condensation of moisture (water vapour) in the atmosphere; formation of cloud, dew, and frost. The heating power of steam. Boil water by passing steam into it. Find roughly what weight of steam will boil a given weight of water.

Distinction between dissolving and melting. Determination of soluble, insoluble, and partially soluble substances used in the household. The amount of solid matter contained in common beverages is very small, and the food value is not therefore great. Repeat experiment with milk. Foods must be rendered soluble before they can pass into the blood stream and so nourish the body.

Distillation—a double process of evaporation and condensation. Liquids can be distilled, but solid substances dissolved in water do not usually undergo change. Distil a mixture of water, salt, and ink; examine residue and distillate.

Third year (*about* 13 *to* 14 *years of age*).

Repeat the experiments of drying and burning animal and vegetable foodstuffs quantitatively. Completely dry (without burning) weighed quantities of finely divided fat and lean meat, bread, and potato; find percentage loss of moisture. Heat weighed quantities of the dried foodstuffs on a crucible lid until all carbon has burnt away and a mineral ash only is left. Find the percentage of ash in the food-materials. Refer to loss of weight during roasting and baking; the water contained in food-materials has no value as nourishment, the mineral ash or 'salts' are needed in the blood and for building up the harder structure of the body.

The transference of heat; illustrate conduction, convection, and radiation by the ways in which an oil-lamp or gas-jet loses its heat. Conduction: coat wires of iron and copper with wax, bind the ends together and heat the junction; show that the heat is conveyed more quickly and further along the copper than the iron; metals generally are good conductors of heat; wood, glass, water, and air are bad conductors. Some substances in a room feel warm and some cold when touched, though all are at the same temperature. Linen sheets feel colder than calico sheets or a blanket. Wool a bad conductor, chiefly because it contains so much air; cotton wool. Refer to clothing materials, and the fact that wool absorbs perspiration and keeps the skin dry; other domestic application of conductors and insulators of heat.

Convection: heat carried by heated particles of a liquid or gas moving and communicating their heat to objects with which they come into contact. Revise the lessons on ventilation and circulation of hot water, ocean currents, winds. Radiation: the transference of heat energy independently of intervening media. Simple experiments to show that objects exposed to radiant heat of fire or sun are hotter than intervening air. Application of modes of transference of heat to the familiar methods of cooking.

The effect of surface and colour on radiation and absorption of heat. Black and white clothing materials. Reflection of heat from bright surfaces; application to stoves. Modes of heating by closed stoves and open fires; necessity for carrying away products of combustion.

The burning of a candle in a closed vessel of air; disappearance of some air during the burning; nature of residual inactive gas; similar effects when a small lamp burns in a bell-jar over water.

Pass a slow current of air over bread or carbon heated in a glass tube; collect and examine the issuing gases with a lighted taper, litmus solution, and lime-water. Notice that the faster air is passed through the tube the more rapidly the carbon burns and the greater the heat produced.

Inhale and exhale air through lime-water. Collect some jars of breathed air. Test with taper, litmus, and lime-water. Breathing and burning have much the same effect on the air. The body is nearly always hotter than its surroundings; but in health never varies in temperature. How is this? There must be an internal supply of heat, due to a slow or 'wet' burning of food-material in the body. Refer again to loss of body heat by evaporation of perspiration on skin and to prevention of loss of heat by clothing. Very simple description of organs of breathing—the lungs, mouth, nose, diaphragm, and rib muscles—importance of deep breathing, fresh air, well-developed and unrestricted breathing apparatus.

Metals such as iron, copper, lead, and magnesium, strongly heated in the air, form scales and increase in weight. Air passed over heated metals is inactive, and will not support burning; this inactive air is not acid, nor will it affect lime-water.

Phosphorus and sulphur burnt in air produce a diminution in volume of air, and acid products which dissolve in water; the residual air is inactive and does not affect lime-water. Determine the proportion of active air by burning phosphorus in a tube.

Examination of iron rust. Rusted iron is heavier than the iron from which it is formed. Iron will not rust in water free from air. The air affected by rusting iron to the same extent as by burning substances; the residual gas is inactive, is not acid, and does not affect lime-water.

The active part of air—preparation from red lead and 'oxygen mixture'; the properties of active air: the formation of acids when phosphorus, sulphur, and carbon are burnt in it. Hence the name 'oxygen'; compounds with oxygen called oxides.

Air evidently composed of inactive air (nitrogen) and active air (oxygen) in proportion of about four to one. Oxygen added to inactive air from rusting iron or burning phosphorus forms a mixture similar in properties to air.

Repeat experiment of heating wood and some food-materials in hard glass tube; notice that gases evolved only burn in contact with air, and that the charcoal produced will not burn in the tube, but will burn in the air.

Oxygen passed over heated carbon produces a gas which is acid, affects lime-water, and will not support the combustion of a taper—carbonic acid gas. It is similar to the gas exhaled from the lungs. Magnesium will burn in this gas producing carbon and magnesium oxide, showing by analysis that carbonic acid gas is composed of carbon and oxygen.

A slow stream of oxygen passed over a column of red hot carbon produces some carbonic acid gas; but also large quantities of an inflammable gas—carbonic oxide—often seen on the surface of a clear coke fire. The two oxides of carbon; the nature of flame; care and use of oil lamps.

Revision lessons on the chief types of foodstuffs—starch and sugar, fat and lean. All contain carbon; some when burnt produce a pungent odour of burnt feathers: these contain nitrogen, and are known as proteids. Flour contains starch and gluten (proteid). Eggs contain albumen (proteid) and fat insoluble. Starch is easily convertible into sugar. Fats contain no nitrogen, but are usually easily melted and rendered soluble by alkaline substances.

The fermentation of starch and sugar by yeast; production of alcohol and carbonic acid gas. Distillation of a fermented liquor; preparation and properties of alcohol; making and baking a loaf of bread; the yeast used as a means of making dough spongy by setting free carbonic acid gas in all parts.

The nature of alcohol; its value as a food and as a stimulant; its effects on the body when taken in excess; it gives no additional strength, but acts as a whip to the body, and enables it to use its energy faster than it otherwise would. The great dangers attending the use of alcohol.

Yeast substitutes employed for the purpose of rendering dough spongy, so that it will be easily attacked by the digestive juices, which must dissolve it before it can get into the blood stream and nourish the body. The nature of bread, soda, and baking powder; the conditions under which they evolve gas.

Fourth Year (about 14 *to* 15 *years of age).*

The chief sources of water-supply for domestic purposes; deep wells, surface wells, rivers, lakes, rain; the chief properties of these waters and the impurities they contain. Evaporate to dryness in a weighed basin a litre of rain water and of the ordinary supply, and weigh the residue. Detection of organic matter by potassium permanganate. The function of water as a food: acts as the solvent and carrier of the food-material that nourishes all parts of the body, and is necessary to the chemical changes continually taking place; other domestic uses of water, *i.e.*, cleaning, draining, &c.

Hard and soft waters: evaporate a litre of each to dryness and determine 'total solids.' Notice difference in 'feel' of each, and action of soap upon them. Compare hardness of two waters by finding the least quantity of a soap solution which will create a permanent lather with 50 c.c. of each water. Boil some of the hard water and again ascertain how much soap solution is required to produce a lather. Boil some hard water in a glass vessel and notice what occurs. Examine the 'fur' deposited on inside of kettle in which hard water is boiled.

The various ways in which water may become contaminated. Special danger of shallow wells near agricultural land. Drainage of cesspools and leaky drains into water-supply. Necessity of periodical cleaning of storage tanks. Pollution of rivers. If water is muddy it should be filtered through sand. Most dangerous impurity is organic matter, as this mostly means the presence of germs of disease (bacteria). If water is thoroughly boiled for fifteen minutes it may be regarded as safe to drink, but not otherwise unless from a good town supply. Filters, unless very frequently cleaned, are dangerous, as they may collect organic matter, and form a convenient feeding ground for bacteria.

Inflammable gas, originally called 'inflammable air,' is evolved in many cases when metals such as zinc, iron, and magnesium are acted upon by hydrochloric acid (spirits of salt) and sulphuric acid (oil of vitriol); 'inflammable air' burning in ordinary air forms a liquid which on examination is found to be water. 'Inflammable air' hence called hydrogen gas.

Hydrogen gas, passed over hot oxides, *e.g.*, copper oxide or lead oxides, removes the oxygen forming water and the metal. Steam passed over iron forms iron oxides and hydrogen gas. Water is hence oxide of hydrogen. Hydrogen present in all food-materials, and, like carbon, undergoes oxidation in the body to form water.

The general properties of acids and alkalis; hydrochloric, sulphuric, and nitric acids; sodium carbonate and caustic soda, lime, potash, ammonia.

Acids and alkalis react with each other to form neutral substances called 'salts.' Prepare a sample of common salt by exactly neutralising caustic or washing soda with hydrochloric acid (spirits of salts); the action of acids and alkalis on colouring matters (litmus) and on fabrics.

Differences between lime and chalk. The slaking of lime with water. The lime-kiln. Loss of weight when chalk is converted into lime. Collection of chalk gas.

Action of acids on lime and chalk. Preparation of 'chalk gas' which is found to be identical with carbonic acid gas. The weight or volume of 'chalk gas' obtained from one gram of chalk, marble, and kettle 'fur'; action of carbonic acid gas on lime-water, and production of artificial temporarily hard water.

Conversion of washing soda into caustic soda; caustic soda converts insoluble fat into soluble soap.

Manufacture of soap; different alkalis and different fats employed. The best soaps for domestic purposes.

The elements entering into the composition of the body—carbon, hydrogen, nitrogen, and oxygen, with small quantities of sulphur, phosphorus, and the metals calcium, potassium, magnesium, sodium, and iron. These occur chiefly in form of (*a*) water, (*b*) organic matter, and (*c*) mineral salts. The products of combustion of food-material and waste food are excreted; this loss must be made good in form of food; to feed the body properly, without excess of any one type of food, the diet must be mixed, and contain lean, fat, starch, and sugar.

Revision lesson on food as the fuel of the body and the chief types of food-stuffs. Lean, fat, and starch are all necessary for all the chief functions of food.

A very simple treatment of the structure and function of the digestive system, the mouth, stomach, intestines, liver, and pancreas.

The principal changes that foods undergo in the human body; how the food-material gets into the blood stream.

The simple physiology of respiration and circulation of the blood; the heart, lungs, and circulation of the blood.

Germs of disease (bacteria); conditions favourable to germ life; the useful work of germs in destroying refuse matter and rendering it available for plant nutrition. The close relationship of dirt and disease; the reasons for personal and domestic cleanliness.

APPENDIX C.

Contracted Scheme of Work for Small Schools where the upper classes are grouped for instruction in this branch. In order that the ground covered in successive years should not be identical, two parallel schemes, A and B, are suggested to be taught in successive years; the introductory part of each scheme is the same, but different subject-matter is dealt with in the latter part of the schemes.

First Year.—Scheme A.

Build up rectangular solids from cubes and deduce the rule for finding the volume of a rectangular solid or space. The reasons for selecting the cube as the unit of volume.

The graduated cylinder, burette, and pipette; methods of use. Compare volumes of a water-tight rectangular box obtained by (*a*) direct measurement, (*b*) by measuring in the graduated vessels the water it will hold.

Measurement of volumes of small solid by displacement of water in the graduated vessels, or of larger bodies, *e.g.*, potato, egg, by 'overflow jar.'

The balance—adjustment and use; weight of cubes of wood, potato, egg, &c., to $\frac{1}{100}$ gram.

Weight of volumes of water (30, 40, 50 c.c., &c.), measured from burette and pipette, leading to the fact that a cubic centimetre of water weighs one gram. Repeat experiments with hot water.

Weight of known volumes of milk, diluted milk, skimmed milk, cream, beer, spirits, tea, &c. Leave 100 c.c. of fresh milk to stand in graduated cylinder, measure number of c.c. of cream. Show that measurements of weight and volume are used as an indication of quality or adulteration, and that the small amounts of solid matter in tea, spirits, beer, as indicated by weights of unit volume, imply small food-value.

Simple experiments and illustrations to show reality of air. The three states of matter—solids, liquids, and gases. Air, an invisible gas like coal-gas, but having no smell, is not so easily recognised. Refer to use of bellows and bicycle pump. Pass air through water and collect it.

Methods by which air may be extracted from a vessel; experiments to show that air has weight and that hot air is lighter than cold air and will rise above it; application to natural ventilation; simple experiments to show that air exerts a pressure on bodies.

The pressure of the air can hold up long columns of water, but can only support about thirty inches of mercury; construction and use of barometer; daily weather observations.

General nature of changes produced by heat:—

(*a*) Rise of temperature or increase in hotness; refer to exceptions when change of state occurs; heat energy is then employed into converting solid into liquid, or liquid into gas, and not in making the substance hotter.

(*b*) Changes in appearance, *e.g.*, an iron poker or piece of asbestos heated.

(*c*) Changes in mechanical properties, *e.g.*, change in hardness, pliability, malleability, when iron is heated.

(*d*) Changes in substance, *e.g.*, when coal is burnt, metals are heated, limestone is burnt in lime-kiln, an egg is boiled: these changes, in which a new substance is formed, are called *chemical* changes, as distinct from the temporary *physical* changes mentioned above.

Effects of heat upon water. The boiling of water and condensation of steam; water vapour an invisible gas present in the air at ordinary temperatures. Cloud, rain, dew, frost, snow.

Distillation of a fermented liquor and the separation of alcohol from water; nature of alcohol; its use and abuse. The freezing of water; bursting of pipes.

Evaporation, water vapour; loss of heat during evaporation; evaporation of perspiration on the skin; power of fabrics (especially wool) to absorb and condense water vapour from the air; weight of a carefully dried roll of flannel on a fine day and on a wet day. Necessity for thoroughly drying clothes after washing, and again before use. Dangers of damp clothes and damp beds; 'airing' insufficient to dry them properly unless weather is very fine.

Soluble, partially soluble, and insoluble substances; separation of soluble from insoluble substances by filtration; most soluble substances dissolve more readily in hot than in cold water; distinction between dissolving and melting. Filtration of dirty water. Water used for drinking purposes should be thoroughly boiled if there is any reason to suspect impurities.

Simple experiments to show that liquids expand when heated. The thermometer an instrument for measuring hotness or temperature. Illustrations leading to the distinction between heat energy and temperature.

Simple experiments to show that air expands when heated, and that therefore hot air is lighter than cold air; air currents due to differences in temperature. Necessity for and means of obtaining a supply of fresh air.

Changes observed when typical foodstuffs, *e.g.*, bread, cheese, fat, and lean meat, are strongly heated until ash remains; the presence of carbon, and the fact that food is a combustible substance shown.

Determine the amount of moisture in such food-substances as fat and lean meat, bread, turnip, potato (raw and cooked). Mince the material (5 to 10 grams) very finely and weigh it in a weighed evaporating basin; dry it either by placing the dish on a small saucepan containing boiling water or by placing it in a cool oven until no further loss of weight occurs.

Heat strongly some food-materials dried as above until only a grey ash remains; determine the percentage of ash in the original food. Show that the value of a food-material depends upon the amount of dry solid nourishment contained; that most beverages (milk excepted) contain little real nourishment. Determine the amount of dry solid matter in a cup of milk, a cup of tea, a glass of beer or whisky.

Second Year.—Scheme B.

Build up rectangular solids from cubes and deduce the rule for finding the volume of a rectangular solid or space. The reasons for selecting the cube as the unit of volume.

The graduated cylinder, burette, and pipette; methods of use. Compare volumes of a water-tight rectangular box obtained by (*a*) direct measurement, (*b*) by measuring in the graduated vessels the water it will hold.

Measurement of volumes of small solids by displacement of water in the graduated vessels or of larger bodies, *e.g.*, potato, egg, by 'overflow' jar.

The balance—adjustment and use; weight of cubes of wood, potato, egg, &c., to $\frac{1}{100}$ gram.

Weight of volumes of water (30, 40, 50 c.c., &c.) measured from burette and pipette, leading to the fact that a cubic centimetre of water weighs one gram. Repeat experiments with hot water.

Weight of known volumes of milk, diluted milk, skimmed milk, cream, beer, spirits, tea, &c. Leave 100 c.c. of fresh milk to stand in graduated cylinder; measure number of c.c. of cream. Show that measurements of weight and volume are used as an indication of quality or adulteration, and that the small amounts of solid matter in tea, spirits, beer, as indicated by weights of unit volume, imply small food-value.

Simple experiments and illustrations to show reality of air. The three states of matter—solids, liquids, and gases. Air, an invisible gas like coal-gas but having no smell, is not so easily recognised. Refer to use of bellows and bicycle pump. Pass air through water and collect it.

Methods by which air may be extracted from a vessel; experiments to show that air has weight and that hot air is lighter than cold air and will rise above it; application to natural ventilation; simple experiments to show that air exerts a pressure on bodies.

Draw air into the lungs through lime-water, and expel it again from the lungs through lime-water. By breathing on a slate show that breathed air is highly charged with water vapour. Expose dishes of lime, lime-water, and calcium chloride to the air to show presence of moisture and something that turns lime-water milky; show that a candle will not burn in breathed air. Simple methods of ventilating a room: doors, windows, chimneys.

Burn a candle in a jar of air; it will burn if a continual stream of fresh air is admitted; if not, it goes out; measure the air absorbed during the burning; what fraction of the whole is it? The air left after the candle has burnt in it turns lime-water milky, and will no longer support combustion. Repeat experiment with a small lamp and phosphorus; examine and measure in each case the inactive air left after the burning.

Observe carefully the effects of heating fuel—coal, wood, peat—in a tube closed at one end, and in the open air. Inflammable gases produced which burn only when they meet the air. Carbon or charcoal, which will not burn in the tube, but in the open air, always burns without flame, leaving a small amount of mineral ash.

Preparation and examination of oxygen. All substances that burn in air burn more vigorously in oxygen, producing the same products of combustion as when burnt in air.

Carbon burnt in a slow stream of oxygen gas. Preparation and properties of carbonic acid gas (oxide of carbon). Air breathed from our lungs contains carbonic acid gas. Analysis of carbonic acid gas by burning magnesium in the gas.

Nature of acids—corrosive, dissolve metals and many mineral substances insoluble in water; the action of acids—*e.g.*, vinegar, spirits of salt—upon chalk, washing-soda, bread-soda. The action of acids on vegetable colouring matters. Preparation and properties of 'chalk gas' obtained by action of acids on chalk, marble, soda, &c.

The nature of alkalis—lime, soda, ammonia—their action on colouring matters and upon acids. *Exactly* neutralise some acid, *e.g.*, spirits of salt, with an alkali, *e.g.*, soda, and show that the resulting compound is neutral, possessing neither the properties of acids nor alkalis.

The burning of food in the human body a sort of slow or wet burning, which maintains the temperature of the body many degrees above that of its surroundings. Carbon the chief constituent of the body food or fuel, and carbonic acid gas the principal product of combustion.

The principal functions of the digestive organs treated very simply to show how food is transferred to the blood stream, and so becomes available for nourishing the whole of the body.

The importance of germs in daily life; germs or bacteria are minute moulds, which break up complex organic matter into simpler substances; some kinds are harmless to man, others if introduced into the blood stream cause diseases, *e.g.*, measles, typhoid, small-pox; bacteria thrive best under conditions of darkness, moisture, warmth, and dirt. Necessity for cleanliness, fresh air, and sunlight.

APPENDIX D.

List of Apparatus for Elementary Science Course.

For a School NOT provided with a special Science Room in which experimental work can be carried out by all the Pupils simultaneously.

Quantity	Description of Apparatus		Approximate Price s. d.
	GLASS.		
2	*Barometer tubes*, thick glass, 36 inches long, 3 mm. internal diameter	each	0 5¼
1	*Beakers*, Bohemian glass, Nos. 2, 3, 4, and 5 .	per set	1 6
1	*Bell-jars*, unstoppered, 9 inches high, 5 inches diameter at base, neck 1½ inch diameter .	each	0 10½
3	*Bottles*, 2-oz. stoppered, N.M.	each	0 2
2	Ditto, 6-oz. stoppered, N.M.	each	0 2½
3	Ditto, 20-oz., with sand-blasted labels—'Sulphuric acid' 'Nitric acid' 'Hydrochloric acid'	each	0 6
3	Ditto, unstoppered, 7 inches high to shoulder, about 3 inches diameter, with mouth 1½ inch diameter . .	each	0 3¾

List of Apparatus for Elementary Science Course—continued.

Quantity	Description of Apparatus		Approximate Price s. d.
1	*Burettes*, 50 c.c., in tenths, with spring clip and jet	each	2 2
2	*Calcium chloride tubes*, straight, 1 bulb, 6 inches	each	0 $1\frac{1}{4}$
4	*Clock glasses*, 4 inches diameter	each	0 $1\frac{1}{4}$
2	*Combustion tube*, hardest Jena, $\frac{3}{4}$ inch diameter	per lb.	1 5
1	*Condensers*, body 12 inches, with I.R. stoppers, bored for condensing tube and water supply	each	3 3
3	*Conical flasks*, Bohemian glass, 5 oz.	each	0 $2\frac{1}{4}$
3	*Flasks*, Florence, with round bottom, fairly heavy, 12-oz.	each	0 3
3	Ditto, German, with flat bottom, 6-oz.	each	0 $1\frac{1}{2}$
2	*Funnels*, 3 inches diameter, angle tested	each	0 $3\frac{3}{4}$
2	*Gas jars*, $7\frac{1}{2}$ inches high, and $1\frac{1}{2}$ inch diameter	each	0 $4\frac{1}{2}$
1	*Graduated cylinders*, 100 c.c.	each	1 $0\frac{3}{4}$
1	*Pipettes*, 50 c.c.	each	0 7
1	Ditto, 10 c.c.	each	0 $4\frac{1}{4}$
3	*Plates*, ground glass for gas jars	each	0 $0\frac{1}{4}$
$\frac{1}{2}$	*Glass rod*, assorted	per lb.	0 $8\frac{1}{2}$
2	*Test tubes*, thin glass, 6 inches by $\frac{1}{2}$ inch	per doz.	0 $3\frac{1}{4}$
$\frac{1}{2}$	Ditto, to fit conical flasks [item 13], $\frac{5}{8}$ inch diameter	per doz.	0 $2\frac{1}{4}$
2	Ditto, hard glass, 6 inches by $\frac{3}{4}$ inch	each	0 $2\frac{1}{4}$
1	*Thermometers*, 10° C. to 110° C., graduated on stem	each	2 1
1	Ditto, 0° C. to 35° C., in fifths of a degree with paper scale	each	1 11
$\frac{1}{2}$	*Thermometer tube*, fairly wide	per lb.	1 5
3	*Thistle funnels*, 14 inches	each	0 $1\frac{3}{4}$
1	*Troughs*, strong glass, 8 inches diameter	each	0 $11\frac{1}{4}$
2	*Tube*, quill, assorted, soft glass, $\frac{3}{16}$ to $\frac{3}{8}$ inch outside diameter	per lb.	0 $8\frac{1}{2}$
2	**U**-*tubes*, 4 inches by $\frac{1}{2}$ inch	each	0 $2\frac{1}{2}$
$\frac{1}{2}$	*Watch-glasses*, 2 inches diameter	per doz.	0 $4\frac{3}{4}$
4	*Winchester quart bottles*, green glass, without stoppers	each	0 $4\frac{1}{2}$
	PORCELAIN, STONEWARE, &c.		
—	*Beehives*, earthenware, 3 inches and $2\frac{1}{2}$ inches	each	0 4
2	*Boats*, porcelain, 4 inches for $\frac{3}{4}$ inch combustion tube	each	0 $4\frac{1}{2}$
3	*Crucibles*, Berlin porcelain, with lids, $1\frac{1}{2}$ inch diameter	each	0 $4\frac{3}{4}$
3	*Evaporating dishes*, 4 inch Berlin	each	0 7
3	Ditto, 2 inch ditto	each	0 $3\frac{1}{2}$
1	*Pestles and mortars*, earthenware, 3 inches diameter	each	0 $8\frac{1}{2}$
1	*Troughs*, stoneware, 10 inches diameter	each	1 $2\frac{1}{4}$
	INDIARUBBER.		
1	*Stoppers*, for bell-jars [item 3], 1 hole	each	0 $8\frac{1}{4}$
1	Ditto, for W.M. bottles [item 7], 2 holes	each	0 $8\frac{1}{4}$
4	Ditto, for $CaCl_2$ tubes [item 9], 1 hole	each	0 $1\frac{1}{4}$

List of Apparatus for Elementary Science Course—continued.

Quantity	Description of Apparatus		Approximate Price s.	d.
2	*Stoppers*, for conical flasks [item 13], 2 holes .	each	0	$2\frac{1}{2}$
2	Ditto, for Florence flasks [item 14], 1 hole	each	0	$2\frac{1}{2}$
2	Ditto, for Florence flasks [item 14], 2 holes	each	0	$2\frac{1}{2}$
2	Ditto, for German flasks [item 15], 1 hole	each	0	$2\frac{1}{2}$
2	Ditto, for German flasks [item 15], 2 holes	each	0	$2\frac{1}{2}$
3	Ditto, for test-tubes [item 23], 1 hole .	each	0	$1\frac{1}{4}$
4	Ditto, for U-tube [item 32], 1 hole .	each	0	$1\frac{1}{4}$
2	Ditto, for W. qt. bottles [item 34], 2 holes	each	0	$2\frac{1}{2}$
8 ft.	*Tubing*, black, best, $\frac{1}{4}$-inch	per ft.	0	$3\frac{3}{4}$
8 ft.	Ditto, $\frac{3}{16}$-inch	per ft.	0	$3\frac{1}{4}$
8 ft.	Ditto, $\frac{1}{8}$-inch	per ft.	0	$1\frac{1}{2}$
	METAL.			
1	*Bunsen burners*, without rose, diameter of tube, $\frac{3}{8}$-inch	each	0	8
1	*Calorimeter*, spun copper, 3 inches high, 2 inches diameter	each	0	$9\frac{1}{4}$
1	*Copper gauze*, fine	per sq. ft.	0	$11\frac{3}{4}$
1	*Copper tape*, 12 inches by $\frac{1}{2}$ inch by $\frac{1}{16}$ inch .	per strip	0	$3\frac{1}{4}$
1	*Copper wire*, bare No. 16	per lb.	1	1
1	*Cork borers*, set of six, 4 mm. to 11 mm. .	per set.	2	1
1	*Deflagrating spoons*	each	0	$3\frac{1}{4}$
2	*Files*, triangular, with handles	each	0	$3\frac{3}{4}$
1	Ditto, round, with handles	each	0	$3\frac{3}{4}$
1	*Gas connectors*, for slipping over fishtail burners	each	0	9
1	*Fletcher Argand burners*, $\frac{1}{2}$ inch, with tripod	each	2	6
4	*Iron borings*, free from grease	per lb.	0	$0\frac{3}{4}$
2	*Iron gauze*, fine, 6 inches square . . .	each	0	1
2	*Iron hoop*, strip 18 inches by $\frac{3}{4}$ inch . .	per strip	0	$1\frac{1}{2}$
1	*Iron wire*, fine [flower wire]	per reel	0	1
—	*Lead shot*	per lb.	0	4
1	*Sandbaths*, iron, heavy	each	0	$1\frac{1}{2}$
—	*Retort stands*, and bench lights, combined, with three rings and one clamp . . .	each	8	0
1	*Screw clips*	each	0	7
2	*Spring clips*	each	0	2
1	*Spreaders for flame*, Russian iron, 3 inches to fit Bunsen	each	0	9
1	*Heavy iron stewpans*, about 13 inches diameter, lid with four holes 3 inches diameter, and covers	each	5	0
1	*Tongs*, crucible, iron, 6 inches	each	0	3
1	*Tripods*, iron, 8 inches by 5 inches, triangular top	each	0	$7\frac{1}{4}$
	WOOD.			
—	*Blocks*, set of six round wood blocks for supports, 4 inches diameter, 5 inches, 4 inches, 3 inches, 2 inches, 1 inch, and $\frac{1}{2}$ inch respectively	per set	1	10

List of Apparatus for Elementary Science Course—continued.

Quantity	Description of Apparatus		Approximate Price
			s. d
1	*Cubes*, of five different kinds of wood [3 ebony] edge 2 cms., and 2 assorted, arranged in wooden box	per box	3 6
1	Ditto, ditto, edge 4 cms.	per box	4 6
1	*Mahogany tables*, for density determinations. to fix over balance pan. See item 113 .	each	0 $5\frac{1}{2}$
4	*Rules*, boxwood, 12 inches, divided into inches and tenths and into centimetres and millimetres	per doz.	1 1
1	*Seesaw*, boxwood rule, 24 inches long, with groove at centre, and wooden wedge to balance it on	each	1 3
—	*Test-tube stands*, 12 holes and pegs. . . .	each	0 $11\frac{3}{4}$
1	*Burette stand*, double clamp and rings for filter	each	4 $10\frac{1}{2}$
	MISCELLANEOUS.		
2	*Asbestos millboards*, 6 inches square . .	each	0 $1\frac{1}{2}$
$\frac{1}{2}$	*Asbestos wool fluff*	per lb.	1 0
—	*Balances* for a charge up to 250 grammes in each pan, to turn to 1 milligramme, protected agate knife-edges, set-screws, and plumb-line	each	30 6
—	*Benzoline lamps*, blast, with upright chimney	each	12 6
1	*Corks*, good assorted, $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch . .	per gross	2 10
1	*Plumbago crucible jackets*, outside diameter 3 inches, tapering to 2 inches; height $2\frac{1}{2}$ inches	per pair	1 $11\frac{1}{2}$
—	*Measuring-tapes*, 22 yards, in case . . .	each	6 2
4	*Pipe-clay triangles*, $2\frac{1}{2}$ inches	each	0 $0\frac{3}{4}$
$\frac{1}{2}$	*Squared paper*, 100 squares to a square inch, size 14 inches by 10 inches	per ream	5 0
$\frac{1}{2}$	*Squared paper*, ruled in square centimetres, size 14 inches by 10 inches	per ream	5 0

Changes affecting Secondary Education.—Report of the Committee, consisting of Sir PHILIP MAGNUS (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Sir WILLIAM BOUSFIELD, Dr. S. H. BUTCHER, Sir HENRY CRAIK, Principal GRIFFITHS, Sir HORACE PLUNKETT, *and* Professor M. E. SADLER, *appointed to take notice and report upon Changes in Regulations—whether Legislative, Administrative, or made by Local Authorities—affecting Secondary Education.*

SINCE the Committee were appointed at Leicester the Secondary Schools Association for England, of which Sir Philip Magnus is Chairman, and Canon Rawnsley Honorary Secretary, has been called into existence, the aim of which is to safeguard the interests of Secondary Schools and Secondary Education generally by the following among other methods:—

1. By promoting interchange of experience among governors of Secondary Schools.

2. By furnishing information and advice to members of governing bodies and others as to the regulations and decisions of the Board of Education and of local education authorities, and as to questions arising on schemes of the Board for Secondary Schools, and on other matters.

3. By communicating with the Board of Education, local authorities, and other bodies in the interests of Secondary Education.

4. By obtaining such alterations in the regulations of the Board and of local authorities and in schemes for Secondary Schools as may seem desirable.

5. By Parliamentary action when necessary.

It will be a question for consideration later on whether the work of the new Association so overlaps that of this Committee as to render the latter unnecessary. The Committee, however, ask for reappointment.

Curricula of Secondary Schools.—Report of the Committee, consisting of Sir OLIVER LODGE (*Chairman*), Mr. C. M. STUART (*Secretary*), Professor H. E. ARMSTRONG, Mr. G. F. DANIELL, Mr. W. D. EGGAR, Professor J. J. FINDLAY, Dr. H. B. GRAY, Professor R. A. GREGORY, Principal GRIFFITHS, Sir WILLIAM HUGGINS, Mr. O. H. LATTER, Sir PHILIP MAGNUS, Professor H. A. MIERS, Mr. T. E. PAGE, Professor J. PERRY, Mr. HUGH RICHARDSON, Professor M. E. SADLER, *and* Mr. A. E. SHIPLEY, *appointed to consider and advise as to the Curricula of Secondary Schools; in the first instance, the Curricula of Boys' Schools; and to consider through a Sub-Committee the Question of the Sequence of Studies in the Science Section of the Curriculum.*

THE Committee are indebted to a Sub-Committee for having undertaken during the year an inquiry into the Sequence of Studies in the Science Curriculum. The Report presented by this Sub-Committee is subjoined.

The Sequence of Studies in the Science Section of the Curriculum.—Report of the Sub-Committee, consisting of Professor R. A. GREGORY (*Chairman*), Mr. G. F. DANIELL (*Secretary*), Mr. W. D. EGGAR, Mr. O. H. LATTER, Mr. HUGH RICHARDSON, *and* Mr. C. M. STUART.

AN inquiry has been conducted into the actual practice adopted and the ideal plan of studies advocated by science-masters in selected public schools of various types, and the Committee thank the science-masters and inspectors who have helped by full, concise, and clear replies to the questions sent to them.

The following extract from the circular letter will show the scope of the inquiry :—

'The Sub-Committee charged to make inquiries about the best sequence of scientific studies in boys' secondary schools (which for purposes of this inquiry may be taken to mean schools other than public elementary or technical institutions) recognise that the actual order in which science subjects are taught depends upon a variety of circumstances. Such are the type of school, local conditions, the future career of pupils, external examinations, and the personal preferences and qualifications of teachers.

'But we suspect that there is a natural order of treatment which is indicated by the mutual interdependence of the subjects, and to an even more important degree by the brain-development of the pupil. We anticipate that from the replies of experienced teachers, inspectors, and examiners we shall obtain trustworthy information on this question.

'It seems of importance to specify the average age of the class in which the work has been done; to describe the method of teaching, giving an indication of the relative importance (*a*) of lectures, tutorial work, laboratory work, and (*b*) of text-books used by the boys, dictated notes, notes composed by the boys. For convenience we adopt the terms "subject-method" and "problem-method" as defined in question 6.'

Questions relating to the Sequence of Studies in the Science Section of the Curriculum of Boys' Schools.

1. (*a*) Name and address.
   (*b*) School.
   (*c*) Type of school and approximate leaving age.

2. Give a list of science subjects studied at your school in the order in which they are taken, bracketing those begun simultaneously, with the approximate average ages of the classes.

3. Indicate the range of the above work, and add remarks on method. It may be useful to give the names of text-books used (if any) and the extent of the books covered. The terms *problem-method, tutorial or lecture and laboratory*, will help to indicate the style of teaching. Refer also to local conditions and personal preference of teacher where these have determined the choice of subjects.

4. At what stage or age can text-books proper—as distinguished from laboratory guides—be introduced with success, and be used jointly with lectures or instead of them?

5. If free to teach any science subjects in any order (within limits of not less than two or more than six hours per week) what order would you select? Please insert in brackets after each subject the range of age. It may be useful to draw arrows to indicate cases in which one subject leads to another.

6. (*a*) Please state your experience of teaching classes of from twenty to thirty boys by *methods other than* the usual 'subject-method,' which treats mechanics, heat, chemistry, botany, &c., as different *subjects*. Give the extent of your experience and estimate the results obtained.

(*b*) From your general experience of science-teaching, would you prefer, in classes of from twenty to thirty boys, to use the '*subject-method*' or the '*problem-method*'? By the latter is understood the treatment of particular problems by utilising the methods of mathematics, chemistry, geology, or other 'subjects' at will.

7. Add further remarks based on experience.

Results of Inquiry.

(The Roman numerals correspond with the numbers of the questions above.)

I. *Status of Persons and Institutions sending Replies.*—The distribution of these circulars was purposely limited. Of the schools replying, twenty-five may be described as secondary schools of the type receiving grants from the Board of Education, and twenty-two as 'Public Schools.' Several inspectors sent replies containing criticism of special value.

II. *On existing Curricula.*—There is general agreement among the curricula reported. We quote reply (2) as typical of schools with leaving age 15 to 16, and reply (43) as typical of schools with leaving age 18 to 19. The former we designate Group A and the latter Group B.

School No. 2 (Group A).

Ages 12–13.—Physical Object-lessons—measurements, densities, thermometry, centre of gravity, moments.

Ages 13-14.—Calorimetry, Boyle's Law, Triangle of Forces ; Chemistry of air, water, chalk, carbon.

Ages 14–15.—Expansion, Vapour Density ; Salt, Chlorine, Sulphur.

Ages 15–16.—Ammonia, Oxides of Nitrogen, Metals, Light, Electricity, Organic Chemistry.

School No. 43 (Group B).

Ages 11–15.—Astronomy, Physiography or Botany.

Ages 14–15.—Practical Mensuration, Elementary Practical Chemistry.

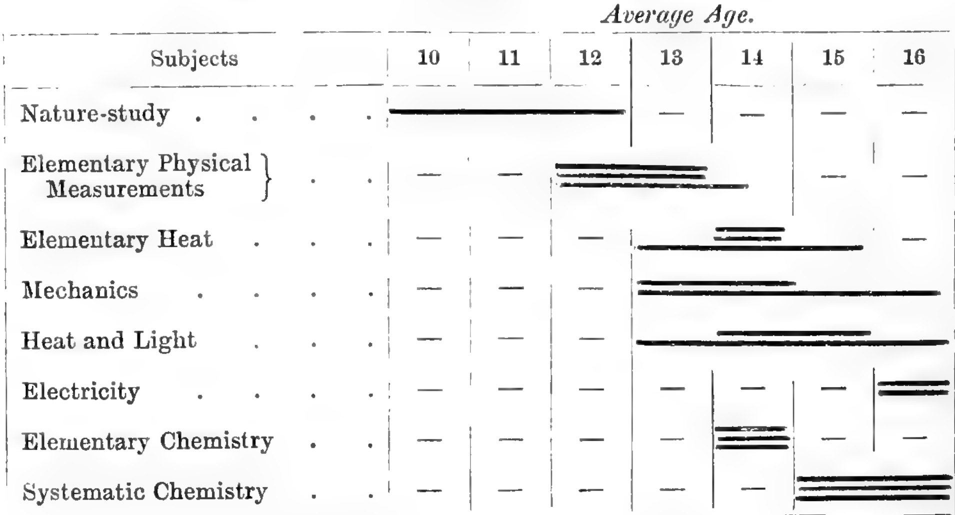
Age 15.—Hydrostatics, Heat ; Chemistry of air and water.

Ages 16–19.—Mechanics, Heat, Light, Electricity and Magnetism ; Inorganic Chemistry ; Elements of Chemical Theory and of Organic Chemistry.

Owing to the close agreement of the curricula, the following tables fairly represent the actual sequence of subjects in the majority of schools :—

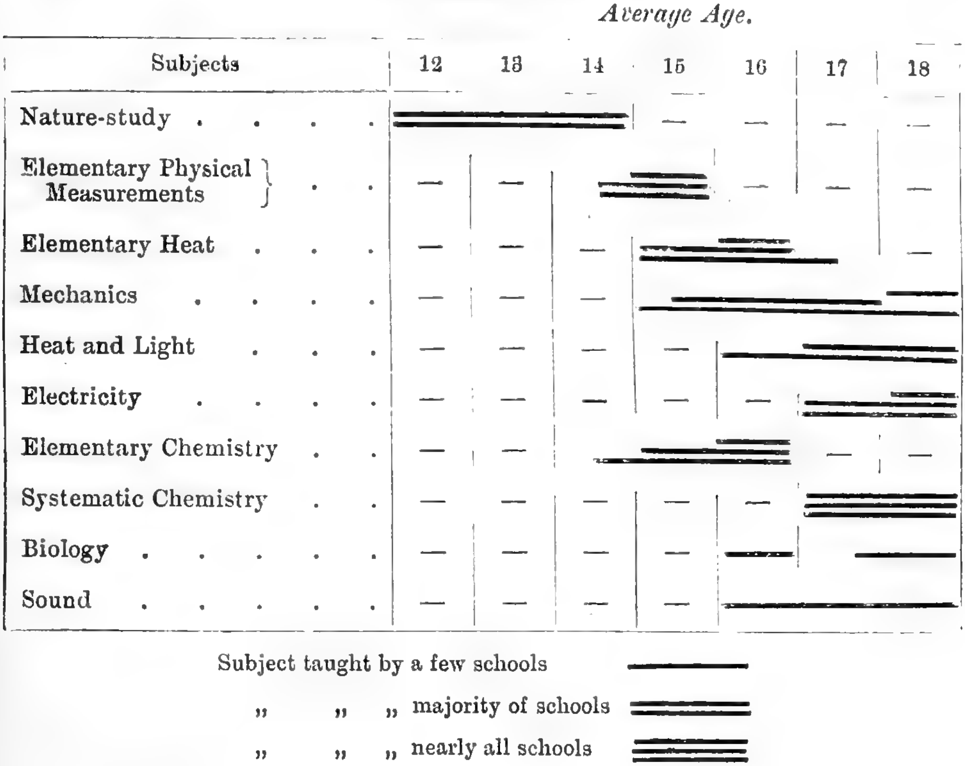
TABLE A.[1]—*Usual science subjects in schools where the leaving age is sixteen.*

Average Age.



[1] See p. 529 for the key to the Tables.

TABLE B.—*Usual science subjects in schools where the leaving age is eighteen.*



Nature-study appears in a minority of Group A and a majority of Group B, and always precedes mensuration, &c. Outdoor and observational studies have made progress since the Nature-study Exhibition of 1902. The work is practical and seasonal. In many schools boys so inclined continue in their leisure hours to work in connection with natural history clubs; otherwise these studies cease somewhat abruptly at age thirteen or fourteen, and seldom lead to the later study of biology.

Elementary Physical Measurements.—By this title we understand such a course as that now contained in the earlier parts of most School-laboratory manuals of physics. Such a course is practically universal; its adoption is supported by the Head Masters' Association, and recognised by examining bodies. The age at which this and other subjects are studied is in accordance with the entrance and leaving ages. Boys of fourteen presumably enter Group B schools without having done the work which is taken from age twelve to fourteen in Group A. In a few cases the elementary practical physics is correlated with mathematics; in many cases the absence of such correlation is deplored.

Elementary Heat.—This subject is universally taught, and may be considered a necessary preliminary to or accompaniment of elementary chemistry.

Systematic Physics.—The branches are usually taken in the order mechanics, heat, light, electricity. In a few cases mechanics is dropped for a time after the conclusion of the mensuration course and begun again on a higher plane with the aid of mathematical equipment at age seventeen. In some Group A schools electricity is introduced early as otherwise the majority of boys leave entirely ignorant of a subject the applications of which will meet them in everyday life. Sound is usually omitted; when introduced it appears late, and is perhaps retained for examination purposes.

Systematic Chemistry, with few exceptions, is studied for the last two years.

Biology.—In Group A schools biology only appears as a class-subject in connection with agriculture. Interesting experiments in rural education are being made, and botany is prominent in the programme; otherwise the absence of botanical teaching in boys' schools is markedly in contrast with the practice in schools for girls. In a few cases lessons in physiology are given at age fifteen-sixteen. As a rule, biology is taught only to boys intended for the medical profession, and is a post-matriculation subject.

Physiography, Geography, and Geology.—We do not include these in our tables, as they do not appear to be among the responsibilities of the scientific staff at present. In a few instances mention is made of them, and some attempts to synthetise a boy's scientific knowledge through the medium of geography are discoverable.

The science work of the classical side of higher secondary schools (Group B) is not sufficiently stated in the replies, the majority of science masters confining their statement of curriculum to the work done in the divisions wherein science is an important branch of the instruction. From statistics presented by Mr. R. E. Thwaites to the Leicester meeting of Section L in 1907, it appears that in secondary day schools all boys over twelve take science, and in twenty-nine public schools less than 60 per cent. of the boys take the general science course of four hours a week. Some of our correspondents state that science on the classical side is very weak; there is no favourable report in this connection.

III. Replies to Questions 3 and 6 are considered together; see VI.

IV. *On the Use of Text-books.*—The reports received are clear and emphatic that text-books are not used, and ought not to be used, in the youngest classes. They are equally clear that text-books are used in the higher classes. At age nearly sixteen, or in Forms V. and VI., or in the last year before an examination, text-books are usefully introduced. The reasons given for using text-books are various—for reference, for preparation, for specialists, for examinees, for revision, for boys who have been absent. Up to fifteen, success appears to depend on carefully prepared lessons, followed by a self-reliant attempt to write a plain, accurate account of what has been done. Text-books when first introduced are employed to supplement the tutorial work, and only at a much later stage, depending on the intelligence of the boys, can a book be employed instead of a lecture—*i.e.*, for the acquisition of facts or apprehension of a course of reasoning. Fairly intelligent boys about fifteen years old, who have been learning science for two years, can use text-books for home work, but not as a substitute for lectures. Many boys appear to have very little power of reading for themselves, but that is perhaps a reason for encouraging them to try. Text-books seem useful in physics rather sooner than in chemistry. There is a loss of keenness on the part of the boys who can find the result of an experiment in the book before they perform it. The use of laboratory guides seems to depend on the preference of the teacher rather than on the intelligence of the boys. Where clear oral directions are given, and all the boys are doing the same experiment, no text-book is required on the laboratory bench. On the other hand, if each boy works at his own pace through a definite course of experiments, some such arrangement is necessary in order to give assistance. Whether the boys shall all do the same experiment at once or work independently is perhaps determined by other circumstances. If the apparatus is limited, the class small, the master not over-busy and helped by a demonstrator, individual teaching is possible with boys who can make some use of books. On the other hand, in large classes, with plenty of apparatus but no demonstrator, the master perhaps relies on very thorough teaching in the lecture-room, the class all do the same practical work, and no text-book is required.

V.—*On the Ideal Curricula in the View of the Correspondents.*—The majority regard the existing curricula as satisfactory, requiring few changes to realise their ideals. The improvements most frequently desiderated are (1) the teaching of mensuration and elementary physical measurements as part of mathematics, (2) inclusion of nature-study where this is not already done. A few ask for the introduction of more biology and of geology, the latter as part of geography. In many schools—probably the great majority—the science master has had a free hand to arrange the curriculum, subject to the demand that some success in external examinations will be achieved. Some public school science masters complain that preparatory schools do not lay any foundation for the science work of the public school.

VI. and III.—*On Present Methods of Teaching.*—Laboratory work is universal, and the importance of boy-made notes is frequently mentioned. In the larger schools a high value is set upon written answers to questions (*a*) set before experimental work in order to focus the ideas of the class upon its purpose, (*b*) set afterwards in order to test grasp of principles. The method of instruction is tutorial, supplemented by what may be described rather as 'lecture-demonstrations' than as 'lectures.' Whereas teachers feel satisfied (as a rule) with their choice of *studies*, many complain of the influence of external examinations on the *methods* of teaching, particularly as hindering, or actually preventing, the adoption of heuristic methods. There is so great a variety of opinion with regard to the value of heuristic methods that we are unable to summarise the replies with justice. We consider that opinion inclines to the adoption of the 'problem-method' in the earlier stages and to the 'subject-method' in the more advanced classes. Almost everyone appears to have tried the heuristic method of teaching, particularly in connection with the chemical side of problems in the laboratory. In the case of nature study the problem-method dominates the teaching, and stimulates boys during the years for which the study is prescribed. With reference to chemistry and physics we quote several statements received :—

No. 1.—'The course follows the order of discovery as developed in my book. . . . I tried the problem-method within one subject—chemistry—for several years. It failed completely ; it was impossible to keep up with twenty boys individually or to keep them together. The method was commended by several competent observers who saw isolated lessons, but although the classes were keen and gave time out of school the result was chaos of mind and the boys became discouraged.'

No. 8.—'Ten years of heuristic work. I am more than ever convinced of its value. . . . No work in the curriculum is valued more.'

No. 12.—'Rigid adherence to subjects is ridiculous in elementary stages.'

No. 16.—'Heuristic method is excellent where boys are few, young, ignorant of science, and it is possible to have the "sets" move up the school together for two years. It breaks down when revising for examination purposes.'

Nos. 17 and 20.—'Employ "problem" and "subject" methods simultaneously; infuse the first method with the spirit of the second.'

No. 22.—'For larger classes even I should prefer the problem-method.'

No. 23.—'Country schools should base curriculum on rural economy and agricultural science, all science "subjects" being drawn upon as required; but it is very difficult to obtain assistant masters capable of using the method.'

No. 24.—'Problem methods tried with success for boys not entering for examinations. Systematic chemistry is a poor school subject. . . . Heuristic method takes too long. The standard of scholarship examinations and the rigidity of pass examination methods and subjects are a curse which prevents one adopting ideal methods.'

No. 25. 'I much prefer the subject method. . . . More interesting to the student.'

No. 26.—'Have had nine years' experience of problem-methods and nine years' previously of subject-methods, and consider that there is no comparison as to the superiority of the problem—*i.e.*, heuristic method. . . . It gives a better insight into the way in which knowledge is and has been gained.'

No. 41.—'Boys are too slipshod in their mode of thought; since it is my chief concern to teach them to concentrate their minds, I prefer the subject-method.'

No. 42.—'Problem method requires smaller classes, better equipment, more laboratory assistants than most schools can command. . . . Problem work cannot be properly examined, and home-work is difficult to arrange; a very high class of teacher is required.'

No. 45.—'The subject-method is preferable for comparatively advanced students, the problem method for beginners.'

An inspector of secondary schools writes: 'It is very rare to find that the result of the teaching is to lead boys to work on their own initiative. Even in schools where the heuristic method is most successfully taught, it is rare to find boys who can apply the methods learnt in previous problems to a new question, even of a related kind.'

A head master writes: 'Subject-method preferable for public school boys. Problem-methods only suited to those who are intensely interested. I consider that those who emphasise the heuristic method have had little experience in teaching discipline, which is essential to learning.'

Sir William Huggins writes: 'It would seem to me, on general grounds, that in the junior classes the first elements of natural science *as a whole*, in a broad way (including mechanics, heat, light, chemistry, electricity, and geology), should be taught by the "subject-method," to be followed later by the judicious addition of the "problem method" in the subsequent study of each science.'

Professor H. A. Miers writes: 'I think that for the more advanced boys it is most desirable that all the science subjects should assist one another, that problems should be discussed which involve an acquaintance with more than one science, and that the tendency to divide science up into separate subjects should be left more and more out of sight as the student advances.'

The difficulty of summarising replies of which the above is a selection is obvious. There appears to be agreement as to the desirability of emphasising the inter-dependence of chemistry and other subjects 'Physical science is one; your teaching must bring this into prominence.'

VII.—*On Special Difficulties to which reference is made in the replies under 'Further Remarks.'*—Several masters complain of the insufficient mathematical equipment of pupils, and of the need of co-operation between mathematical and science masters. Promotions are a source of difficulty owing to their frequency and to the fact that they are often made with entire disregard of the science work. As a consequence, boys in the same set differ much in their ability and knowledge of science. One correspondent protests against the abandonment of qualitative analysis, which in his opinion is of much value, provided boys are made to think. Another states that Universities do little to teach methods of teaching science. From the science masters of a few schools comes the complaint that they are under a classical tradition of overwhelming power, and that their colleagues disparage science. We are happy to say that there are other schools where broader views are found compatible with unsurpassed achievements in the classical languages.

The injurious influence of external examinations, particularly in the early part of the course, is a frequent source of complaint. We quote reply No. 2 in this connection: 'The curse of science work is examinations, especially the compelling of boys to pass in Elementary Science. Nothing is more deadening than the getting up of chemistry for London matriculation. When the experiments have been made and understood, all educational value has been sucked from them; the boys are capable of doing higher work, but they must now grind along the weary round of describing elementary experiments, of learning to recognise that the same question may be asked in ten different ways, and of devising laborious experiments to prove something which is perfectly obvious.'

Opinions and Recommendations of the Sub-Committee.

The following conclusions may be drawn from the results of this inquiry:—

(1) The organisation of the studies of chemistry and physics, and especially their correlation, shows marked improvement, both in secondary day-schools and in the 'sides' of those large public schools in which the science work is regarded as an important part of the general intellectual training.

(2) The attention universally given to laboratory practice and to the development in the boys of the powers of *doing* and *describing* deserves nothing but praise. The considerable degree of freedom given to teachers has clearly encouraged independent experiment and thoughtful criticism as regards their work. The resulting variety and elasticity in their methods is, in our judgment, a good feature which we wish to preserve As indicated below, we desire to give greater freedom to teachers by modification of the influence of examinations.

(3) We are in sympathy with the endeavour of the Public Schools Science Masters' Association to overcome the neglect of science n

preparatory schools. The boys should be made to feel from the first that the study of science is an essential part of their education. Both in the preparatory departments of day schools and in preparatory schools some mensuration should be included as part of the mathematical work. But an essential part of the preparatory course in science should be natural history (including some physical geography) and the rudiments of physics; the real value of these studies depends upon training in observation.

(4) No school course can be considered complete without at least two years' systematic practical work in science. We direct the careful attention of head masters as well as science masters to the problem of how, without over-pressure, to make the study of science an intellectually fruitful and stimulating part of the work in higher secondary schools of those boys whose special gifts are linguistic or literary.

We think that the value of sound scientific literature of a general character and of good lectures, well illustrated, for older and intellectual boys is underrated. Evolution, geology, electricity, optics, sound, human physiology, and astronomy seem suitable subjects. The feeling that there has been of late years a loss of popular interest in science is shared by your Committee, who feel that we must look to the schools to improve matters. While fully recognising the importance of quantitative methods, we feel that qualitative work also deserves encouragement and respect. We wish to avoid producing the student described by Professor J. J. Thomson (Section A, Liverpool, 1896) in the words, 'he commences his career by knowing how to measure or weigh every physical quantity under the sun, but with little desire or enthusiasm to have anything to do with them.'

(5) We are struck with the unanimity shown by our correspondents concerning the influence of external examinations upon the teaching of science. This influence is found to be harmful. The harm is produced partly by having to work along the lines of too rigid a syllabus, but chiefly from the fact that science is intended to teach *principles*, while the examination asks for *details*. A boy may have derived the full benefit from a course of science lessons without remembering the experiments therein; for the examination, however, he has not to repeat these experiments; he has to memorise them, and to study how to reproduce what he remembers in the approved examination style. Anything further from true scientific method could not possibly be conceived.

It has been suggested that the written and practical examination should be replaced by, or include, an oral examination based upon the candidates' own work as shown in his note-books, leading on to its application to other problems, and the plan is worth trying; it is hoped that some examining bodies may be induced to make some experiments in this direction.

Working on the lines of a prescribed syllabus limits the teacher's initiative and discourages research methods. The syllabus in nearly all cases prescribes too much for the majority of schools, and, therefore, too much is attempted in the schools. This prevents sufficient attention to the scientific method of inquiry. There are many branches of science, but one scientific method. This consists in obtaining facts and ideas by experiment or observation, classifying and comparing them, and discovering a formula or principle to express them. All the school work in science should be imbued with the aim of cultivating an appreciation of and familiarity with scientific method. Examinations will continue to impede this aim in so far as the school-work is forced to conform to the examination rather than *vice versa.*

(6) We desire a more extended recognition of geography as a science subject, in association with elementary geology. Rightly taught by means of exercises both in and out of school, geography is capable of providing a training in scientific method, of inspiring interest in natural phenomena, and of co-ordinating work in many branches of science.

(7) We are of opinion that more attention may wisely be given to the claims of biology in upper forms.

(8) We note with satisfaction that the necessary correlation is observed as regards chemistry and physics. We find that there is too little correlation of (*a*) mathematics with physics, (*b*) chemistry with English composition, (*c*) nature-study with art, (*d*) physics with workshop instruction, (*e*) geography with all other branches, especially meteorology and nature-study.

The need for more correlation of mathematics and physics implies the need for more co-operation between teachers of those subjects. We believe that the classification into mathematical sets might be accepted by the science masters as the classification for science sets also. It should be pointed out that much of the work which has been done in the physical laboratory can advantageously be transferred to the mathematical classes. Mensuration, including the greater part of the work frequently described as elementary physical measurements, should be part of the mathematical teaching. The work in the physical laboratory should, even at the beginning, be of a truly experimental character.

(9) We are impressed with the need of bringing all science work into closer touch with everyday experience (see Professor Miers' Address to the Public Schools Science Masters' Association, January 1908, published in an abridged form in the 'School World,' March 1908).

(10) There is a need of inspiring and well-written books on scientific works and achievements. It is unwise to limit a boy's ideas in science to the narrow experience he can gain in a laboratory or can hear in a class-room ; such a course must in many cases lead to distaste for science. On the other hand, we question the value of the stream of elementary text-books continually poured forth. What is wanted is a scholarly literature of science.

(11) There are too few laboratory assistants in secondary schools of all types ; a most wasteful 'economy.'

Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. F. W. RUDLER (*Secretary*), Rev. J. O. BEVAN, Sir EDWARD BRABROOK, Dr. HORACE T. BROWN, 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* PRESIDENT *and* GENERAL OFFICERS. (*Drawn up by the Secretary.*)

THE resolution on the subject of Photographic Surveys, which was sent up by the Conference of Delegates to the Committee of Recommendations at the Leicester meeting, was remitted by the Council to the Corresponding Societies Committee. This resolution deals with three distinct questions, to each of which the Committee have given their attention. The *first* clause of the resolution expresses the desirability of obtaining 'information as to the present state of things in Britain in connection with photo survey-work.' In order to obtain such information the Committee prepared a circular, with a schedule of questions, which was sent, towards the end of last year, to all the Local Societies in correspondence with the British Association. Replies were received from thirty-eight societies, and are preserved for future reference in the office of the Association. These replies give information, in more or less detail, about survey-work in the counties of Devon, Dorset, Essex, Kent, Shropshire, Surrey, Sussex, Warwickshire, Worcestershire, and Yorkshire. It appears from the replies that very little systematic survey-work is undertaken directly by the local scientific societies, but in several cases it is carried on by organisations which are related, more or less closely, to the societies, and in some instances are their direct offspring. It is to be regretted that certain surveys, after having been started with enthusiasm, seem to have lapsed into inactivity.

With regard to the *second* clause of the resolution, which suggests that the British Association should 'publish instructions or give advice for the execution of a scientific photographic survey,' the Committee, while recognising the desirability of co-ordinating the work which is being carried on in different localities, do not feel justified in recommending the Council of the Association to undertake the responsibility of issuing any code of general instructions. The Committee desire to put on record the receipt of a resolution passed by the Council of the Photographic Survey and Record of Surrey, expressing the opinion that 'It is desirable to federate the various Photographic Surveys in this country for the greater furtherance of record work.' Much may, no doubt, be said in favour of federation, but in view of the existence of the National Photographic Record Society, the Committee hesitate to recommend the Council of the British Association to take action in the matter.

The *third* clause of the resolution passed at the Leicester Conference expresses the desire that steps should be taken 'to found or promote a photo-record of the town and district in which the British Association holds its annual meeting.' The Committee are of opinion that it is desirable there should be such a record; and, in an interim Report to the Council, have recommended that the Local Executive Committee of the Association should be asked each year to obtain a collection of photographs of the district visited, and to arrange for the exhibition of the collection during the meeting. Probably the collection could generally be obtained through the medium of the local Scientific Societies. The Committee have heard with much satisfaction that the Council has acted on this recommendation, and that the Dublin Naturalists' Field Club, at the request of the Local Executive Committee of the forthcoming meeting of the Association, is preparing for exhibition a large collection in illustration of the natural history and archæology of the Dublin district. It is hoped that this example will be followed in the future, and that an exhibition of local photographs, systematically arranged, will become a permanent feature of the annual meetings.

The Committee desire to express the deep regret with which they have learnt of the recent death of Mr. W. Jerome Harrison, who moved the resolution at the Leicester Conference, and who had initiated the discussion on photographic survey-work by the paper which he read to the Delegates at the York Meeting.

The Committee beg leave to recommend that the Selborne Society and the Lincolnshire Naturalists' Union be placed on the list of *Affiliated* Societies, and that the Bradford Scientific Association and the Hawick Archæological Society be added to the roll of *Associated* Societies.

Several suggestions with regard to subjects suitable for discussion at the forthcoming Conference of Delegates have been received from the various Corresponding Societies; and the Committee, having duly considered them, have decided to recommend that the following subjects be brought before the Dublin Conference :—

'On detailed Natural History Surveys of Restricted Areas, an important work suitable for Local Societies.' To be introduced by Professor G. H. Carpenter, B.Sc. (Dublin).

'Sanctuaries for our Native Fauna and Flora.' To be introduced by Mrs. Mary Hobson (Belfast).

'The Advisableness of Re-stocking Haunts whence Fauna and Flora have disappeared.' To be introduced by Mr. H. Davey (Brighton).

'On Permanent Records of Natural History or other Observations by means of the Card Catalogue System.' To be introduced by Mr. F. A. Bellamy, M.A. (Oxford).

Professor H. A. Miers, F.R.S., who will preside at the Conference in Dublin, has promised to deliver an introductory address to the Delegates on 'The Educational Opportunities of Local Scientific Societies.'

The Committee ask to be reappointed, with a grant of 25*l*. It may be explained that the annual grant is expended in binding the Proceedings of the Corresponding Societies, in printing and postage, and in obtaining the clerical assistance required for the preparation of the annual Catalogue of Papers selected from the Corresponding Societies' publications. This catalogue, which is of much bibliographical value, is prepared by Mr. H. C. Stewardson, and as the number of Corresponding Societies grows year by year the labour naturally increases.

The Committee recommend that Mr. W. P. D. Stebbing be nominated as Secretary, in succession to Mr. Rudler, who has resigned, after having held the secretaryship of the Committee since 1902.

Report of the Conference of Delegates of Corresponding Societies held at Dublin, September 3 and 8, 1908.

Chairman . . .	Professor H. A. Miers, F.R.S.
Vice-Chairman . .	Professor Grenville A. J. Cole.
Secretary	W. P. D. Stebbing.

The following Corresponding Societies nominated Delegates to represent them at the Conference. The attendance of Delegates is indicated in the list by the figures 1 and 2 placed in the margin opposite to the name of the 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 appointing Delegates.

1	2	Andersonian Naturalists' Society	M. B. Gilmour, F.Z.S.
1	2	Ashmolean Natural History Society of Oxfordshire	F. A. Bellamy, M.A.
1		Bath Natural History and Antiquarian Field Club	Rev. C. W. Shickle, M.A.
1	2	Belfast Natural History and Philosophical Society	John Smyth, M.A.
1	2	Belfast Naturalists' Field Club	Mrs. Mary Hobson.
	2	Berwickshire Naturalists' Club	G. P. Hughes.
		Birmingham and Midland Institute Scientific Society	C. J. Watson.
1		Birmingham Natural History and Philosophical Society	Prof. W. W. Watts, F.R.S.
	2	Brighton and Hove Natural History and Philosophical Society	Henry Davey.
1		Bristol Naturalists' Society	J. H. Priestley, B.Sc.
1	2	British Mycological Society	Carleton Rea, B.C.L.
1		Buchan Field Club	J. F. Tocher, B.Sc.
1		Burton-on-Trent Natural History and Archæological Society	Arthur Slator, Ph.D.
		Canada, Royal Astronomical Society of	Prof. A. T. de Lury, M.A.
1		Caradoc and Severn Valley Field Club	Prof. W. W. Watts, F.R.S.
		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	E. Kitto, F.R.M.S.
1	2	Croydon Natural History and Scientific Society	W. Whitaker, F.R.S.
1	2	Dublin Naturalists' Field Club	G. H. Pethybridge, Ph.D.
		Dumfriesshire and Galloway Natural History and Antiquarian Society	Prof. G. F. Scott-Elliot, M.A.
		East Kent Scientific and Natural History Society	A. S. Reid, M.A.
		Eastbourne Natural History Society	H. Dent Gardner, F.R.G.S.
1	2	Edinburgh Field Naturalists' and Microscopical Society	W. C. Crawford, F.R.S.E.
1	2	Edinburgh Geological Society	R. C. Millar.
1		Essex Field Club	Prof. E. G. Coker, M.A.
	2	Glasgow Geological Society	Prof. J. W. Gregory, F.R.S.
1	2	Glasgow Natural History Society	Peter Ewing, F.L.S.
	2	Glasgow Royal Philosophical Society	Prof. J. W. Gregory, F.R.S.
		Halifax Scientific Society	Wm. 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.
		Holmesdale Natural History Club	Miss Ethel Sargant, F.L.S.
		Hull Geological Society	J. W. Stather, F.G.S.
1		Hull Scientific and Field Naturalists' Club	T. Sheppard, F.G.S.
	2	Institution of Mining Engineers	J. A. Longden, M.Inst.C.E.
		Ireland, Statistical and Social Society of	Sir Robert Matheson, LL.D.
		Isle of Man Natural History and Antiquarian Society	J. Lomas, F.G.S.
		Leeds Geological Association	A. R. Dwerryhouse, D.Sc.
		Leicester Literary and Philosophical Society	Alfred Colson, M.Inst.C.E.
		Liverpool Biological Society	J. Pearson, M.Sc.
		Liverpool Engineering Society	T. Duncanson, M.Inst.C.E.
1		Liverpool Geographical Society	Capt. E. C. Dubois Phillips.
		Liverpool Geological Society	H. C. Beasley.
1	2	London: Quekett Microscopical Club	C. F. Rousselet.
1	2	London: Selborne Society	W. M. Webb, F.L.S.
1		Manchester Geographical Society	J. Howard Reed, F.R.G.S.
1	2	Manchester Geological and Mining Society	Wm. Watts, M.Inst.C.E.
		Manchester Microscopical Society	F. W. Hembry, F.R.M.S.
		Manchester Statistical Society	Prof. S. J. Chapman, M.A.
	2	Midland Counties Institution of Engineers	J. A. Longden, M.Inst.C.E.
1	2	Norfolk and Norwich Naturalists' Society	Frederick Long, L.R.C.P.
		North of England Institute of Mining and Mechanical Engineers	J. H. Marr.
		North Staffordshire Field Club	Sir Thomas Wardle.
		Northamptonshire Natural History Society and Field Club	Beeby Thompson, F.G.S.
		Northumberland, Durham, and Newcastle-upon-Tyne Natural History Society	N. H. Martin, F.L.S.
		Nottingham Naturalists' Society	Prof. J. W. Carr, M.A.
1		Paisley Philosophical Institution	John Woodrow.
1		Perthshire Society of Natural Science	Dr. H. R. Mill, F.R.S.E.
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.
1	2	Southport Literary and Philosophical Society	A. H. Garstang.
		South Staffordshire and Warwickshire Institute of Mining Engineers	J. H. Marr.
		Tyneside Geographical Society	Herbert Shaw, B.A.
1	2	Vale of Derwent Naturalists' Field Club	R. S. Bagnall.
		Warwickshire Naturalists' and Archæologists' Field Club	W. Andrews, F.G.S.
1	2	Woolhope Naturalists' Field Club	Rev. J. O. Bevan, M.A.
	2	Worcestershire Naturalists' Club	Carleton Rea, B.C.L.
	2	Yorkshire Geological Society	J. G. Robinson.
		Yorkshire Naturalists' Union	T. Sheppard, F.G.S.
		Yorkshire Philosophical Society	Dr. Tempest Anderson

List of Associated Societies appointing Delegates.

1		Bakewell Naturalists' Club	E. M. Wrench, M.V.O.
1	2	Balham and District Antiquarian and Natural History Society	Sir Edward Brabrook, C.B.
1	2	Bournemouth Natural Science Society	J. E. Liddiard, F.R.G.S.
1	2	Bradford Natural History and Microscopical Society	W. West, F.L.S.
		Catford and District Natural History Society	A. B. Harding.
		Dunfermline Naturalists' Society	Henry Beveridge.
		Ealing Scientific and Microscopical Society	Dr. W. Deane Butcher.
1	2	Grimsby and District Antiquarian and Naturalists' Society	Dr. O. T. Olsen, F.L.S.
1	2	Hampstead Scientific Society	C. O. Bartrum, B.Sc.
1		Hastings and St. Leonards Natural History Society	C. G. Skyrme.
		Hawick Archæological Society	C. J. Wilson.
		Ipswich and District Field Club	P. G. H. Boswell.
1		Leeds Naturalists' Club and Scientific Association	Harold Wager, F.R.S.
1	2	Lewisham Antiquarian Society	Sir Edward Brabrook, C.B.
		Newcastle-upon-Tyne Literary and Philosophical Society	Prof. M. C. Potter, F.L.S.
		Preston Scientific Society	Edmund Dickson, F.G.S.
		Scarborough Philosophical and Archæological Society	Herbert King, M.Sc.
1	2	School Nature Study Union	Mrs. White, D.Sc.
		Scottish Microscopical Society	Alexander Fraser, M.A.
		Southport Society of Natural Science	D. E. Benson.
		South London Entomological and Natural History Society	Robert Adkin, F.E.S.
1		Teign Naturalists' Field Club	John S. Amery.
1		Torquay Natural History Society	A. Somervail.
1	2	Watford Camera Club	John Hopkinson, F.L.S.

First Meeting, September 3.

The Meeting was presided over by Professor H. A. Miers, F.R.S., Chairman of the Conference. The Corresponding Societies Committee was represented by the Rev. J. O. Bevan, Sir Edward Brabrook, Mr. J. Hopkinson, Dr. H. R. Mill, Mr. W. P. D. Stebbing, and Mr. W. Whitaker, F.R.S.

The Very Rev. Dr. Delany, Principal of University College, having welcomed the Delegates, the Chairman delivered an address on 'The Educational Opportunities of Local Scientific Societies.'

Chairman's Address.

The subject which I have chosen for my brief Address is one to which I think attention may be profitably drawn at the present moment. The opportunities for scientific education have become so changed during the last few years, and yet at the same time the gulf between the amateur and the trained scientist has been in a sense so widened, that the educational position occupied by the Local Societies deserves to be reconsidered.

It will, I think, be generally granted that the London and other central societies are becoming more and more the haunt of the professional scientific man, and I wish to raise the question whether under these circumstances it may not be hoped that the Local Societies will accept an increased responsibility for the amateur, for whom it is true they already do so much? To me, at any rate, it appears that this responsibility is also an opportunity. Let us look back for a moment at their earlier history.

The affiliated and associated societies number some which came into existence nearly a hundred years ago, and many of them date back to a time when there was no organisation which attempted to diffuse a taste for science throughout the country at large. These societies were doing pioneer work, not only by arousing interest in research, but by creating a general scientific atmosphere, and promoting ideas which were at that time confined to a very small class. In fact, before the birth of the British Association they were almost the only agencies occupied in this sort of pioneer work. The British Association itself was initiated by one of them, and may be regarded as a magnified society of the same character, changing its habitat from year to year: the importance of the early work which it effected in popularising and promoting scientific ideas cannot be over-estimated. For a long time the work of the societies was not supplemented in any very adequate manner by the publishers or the Press; public interest in the general laws that underlie the processes of Nature was only dawning; the prevailing attitude of mind was one of indulgent curiosity; the older generation regarded science as a curious and entertaining pursuit, but chiefly fitted to be a pleasing pastime for the young; there was as yet no intellectual thirst for scientific knowledge sufficient to create a demand for a special literature. I am of course leaving out of account for the moment the ardent students and the earnest investigators and teachers who were engaged in laying the foundations of scientific education and research. For the majority, however, especially those who lived out of reach of the great towns and universities, and beyond the personal influence of the few inspired workers and teachers, there were as yet no books which would enable them to acquire the rudiments of real scientific knowledge at home or by individual effort. It was not easy even for those who had a personal interest in some scientific subject to ascertain what progress was being made at the great centres of discovery and research.

It was only at a much later period, after the stimulus had been supplied by the British Association, and by the Local Societies (whose rapid increase was no doubt due in a great measure to the influence of the British Association) that a real thirst for information made itself felt, and created a sufficiently widespread demand for a new class of scientific literature.

This resulted in the appearance of a number of excellent cheap text-books of elementary science, designed to give a certain amount of sound general knowledge and to stimulate the desire for more, and for a considerable time these continued to fulfil precisely the object for which they were intended. If the day of the shilling primers, each including a whole science, seems now to have closed, we must allow that in their time they played a very important part in the history of science in the British Isles. Written by acknowledged leaders of thought, they challenged the attention of educated and intelligent people to whom perhaps science had not meant much before. They were written for and read by those who had not received any advanced scientific training, and who would not have found elsewhere the sort of information that they needed, presented in so instructive a manner. But by fostering the desire for more accurate and detailed knowledge these primers contributed perhaps to their own extinction, for with the increase of special training and the dissemination of expert knowledge they have been more and more supplanted by the educational text-book used in schools, and the specialist treatise which is now put into the hands of the advanced student.

In other words, as scientific literature has become more highly organised it has fallen more and more into the hands of specialists. This is, no doubt, the merest commonplace to all whom I am addressing; but the conclusion that I wish to draw is that from the point of view of the amateur this is to be regretted; for he can no longer get an adequate insight into the modern advances of science without either going through a course of special reading in text-books of various grades—for which he has no time—or attempting to master a treatise which he can hardly be expected to understand without a preliminary training of some sort.

Moreover, it must be remembered that the intelligent amateur no longer necessarily belongs to a class outside scientific circles as he did formerly, but he is frequently quite learned in one branch of science though he may be the merest amateur in another. And yet when he travels outside his own subject he is in danger of being placed in a position somewhat similar to that of his predecessor, the amateur of sixty years ago. For him the introductory text-book is too laborious and in a sense too elementary; the treatise is too technical and is expressed in a language which he cannot understand. On the other hand, the magazine or newspaper article he dare not trust; it is true that excellent articles upon scientific subjects do from time to time appear in the popular magazines, but they are rare: moreover the magazine article comes to-day and is gone to-morrow, and cannot always be secured when wanted. I do not forget that several good scientific journals exist which appeal to a wider public than the specialist; 'Science Progress' in particular, happily revived during the last few years, aims at a very high standard of information, and with conspicuous success. But even here the articles are too often expressed in language which cannot be understood by the ordinary reader.

So far I have referred only to the condition of scientific *literature* in relation to the amateur. But in this Association and at this conference we are concerned rather with the spoken than with the written word; I have only deferred the consideration of scientific meetings in order to draw a parallel.

For if we turn to Scientific Societies, is not what I have said about scientific books still more true about the societies? The greater scientific societies are becoming every day more highly specialised both in their publications and in their membership; there are very few which occupy themselves with more than one branch of science; and even those few which profess to cover a wider field break up into sections, each of which is far too sharply divided from the others.

If it be difficult for the intelligent amateur to extract information from the scientific text-book or treatise, how much more difficult is it for him to learn anything from the proceedings and meetings of these societies? If the language of even the text-books is so thickly beset with technical expressions that it is hard to understand, how much more unintelligible is the specialist jargon of a society in which it often happens that a paper, though read in a meeting of specialists, can only be fully followed by two or three of those present?

Please understand that I am not protesting against scientific terminology in itself, or in its right place; but I do feel that it is discouraging to the earnest inquirer after knowledge to find himself confronted by books which he cannot understand, or condemned to attend meetings where the language spoken is a strange and uncouth tongue which he has no time to acquire.

The result is that our intelligent amateur, whether he be a scientific man or no, is placed very much in the position where he was sixty years ago; and I believe that now, as then, he may find salvation in the local scientific society, if it really attempts to meet his wants.

Cannot the Local Societies, in addition to their ordinary work, make a special effort to satisfy the educational needs of the great many intelligent people who have not been trained in, or have not had access to, laboratories, museums, and scientific libraries, or whose opportunities have not brought them into contact with field-work and the interests and occupations of naturalists, and who desire to know more of science, and perhaps to become themselves workers?

It is true that for their working-purposes, especially if they are naturalist or field clubs, it is advisable for them to break up into sections, one perhaps occupied with the local fauna, another with the local flora, and so on; but if only they could succeed in keeping their members together upon some common ground in which they are united by a general interest in science, and could offer some educational help to members to whom science is chiefly a hobby and a relaxation, they would be doing work which cannot be performed by any other sort of society or by the publication of any ordinary text-book or treatise. In the present state of scientific knowledge and specialisation nothing can be more useful than to bring together persons interested in different subjects and to enable them to understand one another. Very much of the estrangement which now exists between different sciences, or even between the different branches of the same science, is due to the exaggerated use of technical language where it is not necessary, so that a great deal of scientific work is almost entirely unintelligible to the workers in other subjects. The most useful function, in my opinion, that can be performed by the Local Societies, in addition to that of kindling an interest in local problems and in the methods by which they are to be studied, is to encourage a habit of expressing scientific results in simple and intelligible language that will appeal to the whole society. There are very few scientific ideas or facts which cannot be expressed in homely language freed from technical nomenclature, and though it is necessary for purposes of brevity and precision to make use of this nomenclature in the journals and at the meetings of the more specialised societies, it ought to be wholly unnecessary to do so in societies which embrace a number of interests, and whose members are to a considerable extent persons without scientific training. Indeed, nothing can be better or more useful for the scientific specialist himself than to attempt to explain his own work in simple language to a mixed audience; and if the Local Societies can encourage the specialist to come to them and describe his own researches in language which all their members can understand they will do him as much good as they do themselves.

It may justly be urged that there are not many persons able to describe scientific observations or experiments in simple, untechnical language; they are not trained teachers or lecturers. But surely that is all the more reason why they should try to do so; and the Local Society is precisely the place in which the attempt may with advantage be made. It would perhaps be a different problem if the communication were a set lecture of the sort given at schools and universities by professed teachers. For lectures of this kind educational training and experience are no doubt necessary. Perhaps, indeed, there is already too much of the set lecture about the meetings of some Local Societies. But when a speaker is describing something which he has done or seen himself, it ought with a little practice to be easy to give an account that can be understood by a mixed audience as well as by those who are engaged in the same work as the speaker. I believe that the attempt is well worth the making.

The educational opportunities which lie before the local scientific societies can only be developed by co-operation between the professional and the amateur; let the professional scientist become less professional and let the amateur become less of an amateur when they come together at the meetings of such societies. The difficulties with which they have to contend are twofold: on the one hand, there is always the danger lest a paper or a lecture be too special or too technical for the audience because the professional cannot adapt himself to their need; on the other hand, there is the danger lest the audience fall into the habit of expecting too much novelty or entertainment. Everyone must have seen how the utility of a society is undermined by a single pedantic address, which only causes members to drop their attendance, or by the reluctance of some members to attend unless they can expect to be amused by lantern-slides or showy experiments or witty talk. And yet where can better material exist for the teaching of science than among the members of a society who have joined it voluntarily, and in the first instance because they really wished to learn?

My suggestion is that the way to interest and to teach such people is through the description, discussion, and criticism of new research.

An account of some piece of original work actually in course of progress, and described by the enthusiast who is himself carrying it on, is far more interesting and stimulating than any secondhand account in text-books and treatises of the work that has been done at some previous time by others, and should not require any additional embroidery to make it attractive. Anyone who hears a keen naturalist describe the excitement with which he has watched something new in the habits of animal or plant must catch the spirit of enthusiasm, and feel the stir of interest that is the inspiration of all successful teaching and learning.

Perhaps this sort of living interest has been too exclusively confined to natural history communications in some of the Local Societies. In reality the same excitement and the same interest belong to new observations in any and every branch of science.

In fact, I often feel that the sort of book which is really wanted at the present day is a simple untechnical account of the living work by the worker himself. No matter how abstruse or advanced a research may be, there is always something in it which is of surpassing interest if understood, and this can surely be expressed simply and made intelligible without any detailed knowledge of the science in all its bearings. After all, the methods and results of science can just as well be taught by examples drawn from the new work which marks the advancing wave of progress as by what has gone before; and the new thing is always the most interesting.

I am aware that to many it will seem that popularisation of the newest thing in science is being overdone at the present time, and that we hear too much of radio-activity, wireless telegraphy, and the rest. I am suggesting, however, that not only the brilliant discoveries, which most easily attract the public through the Press and fire the popular imagination, should be taken up by the Local Societies, but that the more ordinary work of everyday science, equally necessary and perhaps equally momentous in its consequences, which is at present buried in the proceedings of one sort of society, should be made a real and living thing by the humbler societies of another sort.

I am aware, too, that for educational purposes it is not prudent to introduce children to the newest and imperfectly understood results of modern science until the soil has been prepared by the study of the more mature and better considered work which has gone before; but for the moment I am pleading the cause not of school children, but of intelligent amateurs, many of them persons of exceptional intelligence, some of them persons of considerable scientific attainments and knowledge; before whom both the present achievements of scientific discoverers and the humbler work that is being done by scientific students, whether professional or amateur, may well be laid without all the preliminary training that affords educational exercise to the child at school.

Up to the present, however, I have left out of sight the really great educational advantage that science possesses over all other subjects, namely this: That science is not only talk and thought, but action; that there is always ready to hand, not only something new to be described or narrated, but something new to be actually done by both teacher and pupil. Either some natural object or occurrence to be seen that has never been seen before, or some experiment to be made that has never been made before. It is this which fires the enthusiasm and stirs the imagination, and makes scientific research so enthralling; and the educational work which the Local Societies can best perform, because they are dealing not with children but with men and women, is the encouragement and direction of original research. A good deal is already done by some of them; but on the whole how little compared with what might be done by some co-operation between scientific workers and the societies, and some organisation of the societies themselves. Education requires teacher and pupil; it would not be enough in general that the members of a society should be interested by the address of a specialist and then be left to their own devices to imitate his work and endeavour to research for themselves. This would only, in general, lead to discouragement, if not to disaster. After he has stimulated their interest, they need his guidance and advice. Let him then address them, with the object not of advertising his own researches, but of enlisting the services of fellow-workers. I believe that many a scientific investigator could attract an army of willing workers through the Local Societies if he were given the opportunity of interesting them in his own researches, of suggesting to them lines of simple investigation which they could profitably pursue, and of continuing to guide them by advice and criticism. Something of the sort is occasionally done in the study of the local flora and fauna. That it is not done more widely and in other branches of science is due to the prevalent and growing idea that none can take up any original work without the preliminary of an orthodox scientific training. This I believe to be a great mistake when the teacher is concerned with intelligent people who are no longer children, and who come to him with the desire for work.

In an address delivered this year to the Public School Science Masters' Association, I ventured to illustrate this aspect of education by relating my own experience with a young Frenchman whose previous training and previous work were in the subjects of philosophy and theology, but who desired to have some personal acquaintance with scientific work. I found it possible with him to begin at once with a definite problem of original scientific research (even in a highly specialised branch of science), and to make that the introduction to the general principles of the science which he was studying: beginning with the practical experiments and observations, and working back to their interpretation. In a very short time he was able to publish important results. This is only one of several instances that I might quote from my own experience, but it is the most convincing. The interest and enthusiasm inspired by the feeling that one is making new observations, or in however humble a way working towards a discovery, is quite enough to inspire a longing to understand the general bearing of the work upon which one is engaged. This method would be impossible with a beginner of untrained mind; but it is easy with a mature student who is a beginner only in the sense that he is not a specialist. Far too much time is often spent in preparation which leads to no performance; and much harm is done by discouraging willing learners, because they have not been prepared in the orthodox manner. This is the reason why I see the opportunity for the Local Societies to take up the scientific education of unprepared but mature minds; firstly, by inviting the trained and experienced workers to make known to them, through the medium of untechnical language, the beauty and interest of scientific work in the course of its progress, and of scientific discovery in the making; and, secondly, by providing them with followers who will continue to prosecute under their guidance original observation, and even experimental research.

Everyone knows the success which has attended the University Extension movements, and how an inspiring lecturer has often sown the seed which has produced in literature, art, or science a rich harvest of sincere students.

Let the Local Societies initiate a new Science Extension movement, in which they contribute from their members the willing workers who are ready to act under the guidance and inspiration of those who have had the advantage of special training and experience. Let them attract new members with this object. There are so many persons anxious and able to do something in the way of scientific work who only want the sympathy and guidance of a leader more experienced than themselves; such leaders may not infrequently have to be sought among the teachers or researchers outside the society.

In this way, and by some such co-operation, will the professional cease to be a professional, and the amateur cease to be an amateur, when they meet upon common ground in the local scientific society.

Surely anything that tends to break down the barrier between the professional scientist and the amateur, between expert and layman, is for the good of scientific progress. That the one should ever be actually discouraged by the other seems almost incredible; and yet one has to make the humiliating confession that this happens again and again.

In this connection I would beg you to read the most fascinating and illuminating address delivered to one of our societies, the Yorkshire Naturalists' Union, by Mr. Lamplugh, when he was its President in 1906—an address which protested forcibly against the unhealthy distinction between amateur and professional, and put forward a plea for the need of the amateur spirit in scientific work.

If I have succeeded in this Address in making a practical suggestion that embodies the spirit of his appeal, I may hope in some measure to repay the debt that I owe to one who has always inspired me with the example of true and undivided allegiance to the call of pure science.

It may well be that my views are visionary, and that those who know better than myself the constitution and the work of the Local Societies will pronounce the co-operation which I have suggested to be impracticable. Yet when I remember how many persons I have met in my own limited experience who were burning with the desire to do something in the way of scientific work, and only wanted encouragement and guidance, I feel sure that they are to be numbered by thousands. It is not enough to tell such people what they have to learn and bid them go away and learn it, or when they ask for work to give them words.

Have we not in the Local Societies the agency which can get at these people and organise them as workers? If not, where is such an agency to be found?

I think it a duty incumbent upon those of us who have had the opportunities, and have tasted the rare delight of scientific research, to lend a helping hand to those who desire to share both its toil and its treasure, but have not been able to reach these by the well-recognised path that we have ourselves pursued.

Mr. William Gray (Belfast), in proposing that the thanks of the Delegates be given to the Chairman for his very excellent address, said that he had had the advantage of hearing many important addresses to the Conference, but he had never heard one more appropriate and practical, appropriate because it so clearly defined the proper relation between the work of the Local Societies and the British Association. He said that he could not refer in detail to its practical side, but hoped that he might be permitted to draw attention to one of its suggestions to those who address their fellows—viz., to avoid the display of technical text-book terms and try to convey the results of one's investigations in such language as would be understood by one's fellow-members and friends.

The Rev. R. Ashington Bullen (S.E. Union), in seconding the vote of thanks, said that he trusted that the wise and weighty words of the Chairman would be read and acted upon by the Local Societies. He thought that the Chairman's valuable paper should be read in conjunction with the admirable address of Dr. A. Smith Woodward to the Delegates in 1905.

Professor Miers asked the meeting to pass a hearty vote of thanks to Mr. Rudler for his work as Secretary of the Conference since 1902, and also to Dr. Delany for permitting the meetings of the Conference to be held at University College. These were passed with acclamation.

Mr. William Dale (Hants Field Club and Archæological Society), in speaking of Professor Miers' address, said he thought it pointed to the necessity of Local Societies meeting in the winter as well as the summer. The one with which he was connected met only in the summer, and this was probably the case with many others represented at this meeting. It was only at a winter meeting that a professional scientist could impart information in the way suggested by the Chairman.

The Very Rev. Dr. Delany (University College, Dublin), having thanked the meeting for the vote which they had just passed, said that with the spread of education he thought those societies were most useful which took up subjects relating to man. In instancing the danger of using technical scientific terms, of which so many did not understand the use, he suggested that they should not be used at all. In speaking about the address from the educational point of view, he mentioned, as an instance of what could be done with small means, the work done by the Professor of Botany at the College in laying out and planting a small area at the back of their buildings with hundreds of plants, and so forming an invaluable series for investigation by the students.

Mr. J. Hopkinson (Hertfordshire Natural History Society and Field Club) said that he thought the Hants Field Club was almost if not quite alone in not holding winter meetings. It would be very advantageous to the members of Local Societies if they could get original workers on various subjects to bring their investigations before such evening meetings, disclosing their methods and stating the results at which they aimed.

Sir Edward Brabrook (Balham and District Antiquarian and Natural History Society), who rose to speak on a matter concerning the harmonious working of the British Association and Local Societies, proposed the following motion: 'That the Conference desires to represent to the Committee of Recommendations that whenever a Committee of the British Association enters upon a local investigation notice should be given to any Local Scientific or Archæological

Society, so as to enable that Society to offer any co-operation that may be desirable.' This proposal having been seconded by the Rev. J. O. Bevan (Woolhope Naturalists' Field Club), was carried unanimously.

Mr. Whitaker (Croydon Natural History and Scientific Society), who mentioned that they were not represented on the Committee of Recommendations as a matter of course, then proposed that the Chairman of the Conference should be *ex officio* on the Committee of Recommendations. This having been seconded by Sir Edward Brabrook, was duly carried.

Mrs. Mary Hobson (Belfast Naturalists' Field Club) then introduced the following subject:—

Sanctuaries for our Native Flora and Fauna.

The present moment seems most opportune to introduce the subject before us, for here in Ireland, where the farms are being purchased from the landlords by the tenants, many spots of value to science, of general interest and beauty, are perhaps in danger of disappearing at the hands of the careless or the over-thrifty.

Hitherto the owners of the soil have of intent, or from a lack of interest, been the preservers, and superstition on the part of the country people is responsible for the preservation of many prehistoric remains.

In Ireland the demesnes are to be retained in most cases by the landlords, and it is to the landlords largely we must look for help.

In England only too many demesnes are kept so absolutely 'tidy' that wild life has few spots to call its own; therefore it is suggested that field clubs and other kindred societies should first consider the most likely spots suitable for sanctuaries—say, one in each county or area—and then send a deputation of their members to the owners, asking them to fence them in and guard them from the ravages of intruders, the cost of which would be almost *nil.*

It has been suggested that it might be possible for county councils to set aside waste land, but in Ireland their powers are clearly defined and are limited to ancient monuments; and I am told that rates are levied by the county councils on practically all land, and that in this sense there is no waste ground.

The Irish Land Act, 1903, sect. 14, says—

'(1) When any land which is vested under the Land Purchase Acts in a purchaser contains any ancient monument, which in the opinion of the Land Commissioners is a matter of public interest, by reason of the historic, traditional, or artistic interest attaching thereto, they may, with the consent of the Commissioners of Public Works in Ireland, by order declare that the property in the monument shall not pass to the purchaser, and may make an order vesting the monument in those Commissioners.'

It would be useless to ask the Government to help in Ireland, for so much money is wanted urgently for land for relieving congestion, forestry, &c.

Perhaps the English county councils may have greater powers than the councils here. There are certainly common lands in England which might in some cases be available. I advocate the establishment of sanctuaries without knowing all the possibilities of creating them; knowledge of that kind varies with each district.

Some sanctuaries already exist in this country. Lambay Island has been absolutely protected by the Hon. Cecil Baring. At Glencar, co. Sligo, is a natural sanctuary, not in the demesne, owned by the Wynne family. At Knocknarae Glen, in the same county, the hart's-tongue ferns extend for a quarter of a mile; they have the longest fronds in Britain, and measure up to a yard in length. Lord Clonbrock, at Clonbrock Forest, East Galway, has a sanctuary now carefully preserved, and the only one undisturbed since Elizabethan times.

I do not advocate the preserving of sanctuaries for the shutting out of the 'man in the street,' and admitting solely the man who fondly imagines himself a scientist, because he is making a collection of birds' eggs, plants, &c.

What as scientific societies we should be strenuous about is the collecting of knowledge rather than specimens. In the case of birds the excuse is always 'for identification.'

In these days of books and accurate descriptions and faithful illustrations other pursuits can be studied without having actual specimens; for instance, it is possible for any real student to study the Maoris, or certain tribes in Central Africa, without requiring their mummies in the house. In the same way a man can study the heavenly bodies, the Pyramids, the Pacific tides, without inverting a well-known line, 'hitching a star to your chariot.'

Pick up a journal devoted to such subjects, and you will there read censure of the professional bird-catcher, who makes a living out of his pursuit, and the woman who has the wings of wild, and sometimes rare, birds in her hat. I have not one word to say in defence of either; but what I do object to is the so-called scientific person who is not only collecting but advertising every rare bird. To me it seems absurd for one class to cast stones at the other; if anything the latter is the worse, for because he loves birds he must kill; he also sometimes shoots, wounds, but cannot get the bird, and it is left to die a painful death.

Take the case of Pallas' Sand Grouse; that bird has come before now from its home in Tartary, and been shot. Now attention is being called to its re-appearance, and only the so-called scientific man will recognise it and appropriate it.

The following I copy from one of our local papers for August 8 :—

'At a recent meeting of the British Ornithologists' Club there was exhibited a species of bunting new to Britain. It was shot on Romney Marsh on March 26 of the present year, and is the species known as the Large-billed Reed Bunting (*Emberiza pyrrhuloides palustris*). It is a common species in Southern Spain and Italy. The usual fate of such stragglers is to be shot by enthusiastic ornithologists, which seems a pity, as otherwise they might possibly stay and breed. And it is probable that it is sometimes by such wanderers that the range of a species is extended.'

Have we made up our minds that we want no new birds added to our lists? Are we determined that a bird like this shall not breed on our shores? Is the method now pursued an advantage to science? Let us be frank and answer, 'No.' If we could even preserve the rarer migrants from slaughter we would still have the egg collector, who is quite as destructive as the man with the gun.

For myself, while admiring the art of the taxidermist, I get no pleasure from a glass case of stuffed birds; one is told that such find their way eventually to museums. I venture to say that our curators often resent such methods of dumping indifferent property, which occupies much wanted space.

Museums are the only places justified in having collections of once living things, and at the present rate of activity a time will come when they will be stocked with only what is necessary for the pursuit of knowledge.

In the matter of our native birds it is *bird-watching* that is of value.

Complaints are heard of hedgerows in the vicinity of our cities being denuded of our common ferns, but the genuine botanist, who meanwhile is scouring the country for the rarer sorts, is the first to cry out against the poor town-dweller who has no scrap of garden and few opportunities of seeing the country.

Further, what about those Societies which give a list of every rare plant, &c., on the programme of an excursion, and sometimes offer a prize for the largest collection of wild flowers gathered? It is said that no roots are taken, or rarely; but even so, the more precious the find the greater the loss of the seed.

Let us, if we have any love for science and the life about us, go back to our respective societies and do some little thing to stay the vast destruction going on around.

Mr. Wilfrid Mark Webb (Selborne Society) alluded to the nineteen acres of woodland near London preserved by the Brent Valley and Richmond branch of the Selborne Society as a bird sanctuary. He also expressed his opinion as to the value and necessity of collections, but only when used for truly scientific purposes.

Mr. William Gray (Belfast Naturalists' Field Club) said that Mrs. Hobson omitted to say that the motto of their club was 'Protection, not Obstruction,' and that recently it gave a good example of this. For a number of years a pair of birds, strangers to Ireland, had attempted to breed in the north, but were prevented by a local collector, who had removed the eggs year by year. This past summer the President of the Club had collected funds to be paid conditionally on the successful hatching of the eggs. The result was that the young birds were brought off and allowed to escape without being molested.

Mr. John Hopkinson (Hertfordshire Natural History Society and Field Club) spoke as to the intelligent use by a member of his Society of the field-glass and camera for the observation of rare birds in their breeding haunts, stating that he had been careful not to divulge the sites. He read a letter which he had received that morning, written on the suggestion of an Assistant at Kew Gardens, asking for a number of roots of a rare local plant for medicinal purposes. His Society had a stringent rule against rare plants being uprooted and rare birds and other animals being killed, and this request would not be granted.

The Rev. Ashington Bullen (S.E. Union of Scientific Societies) congratulated Mrs. Hobson on her paper, and emphasised the need of educating public opinion to protect rather than wantonly to destroy rare species. He instanced the destruction of the hoopoe, of which one spring a pair was shot in the New Forest and another (by a friend, who noticed it as a strange bird) in Lincolnshire. Somewhere about thirty years ago one collector took over nine hundred Lulworth skippers in the limited habitat in which it is found: probably the species is on the verge of extinction by this time. Such insatiate greed was worthy of the strongest condemnation. About a quarter of a century ago (1880) the Cornish chough was to be seen on St. Alban's (Aldhelm's) Head, in Dorset. He had heard the jackdaw credited with the disappearance of this species: it was more probable that the charge should be laid at the door of the birds'-nester or sportsman. He believed that the chough was nowhere to be found on the South Coast nearer than Cornwall, and it was diminishing even there.

Mr. Harold Wager (Leeds Naturalists' Club and Scientific Association) expressed the opinion that the collection of specimens for purposes of solving definite scientific problems or for museum collections was no doubt necessary, but that a sound knowledge of natural history, whether of animals or plants, could be obtained without the indiscriminate and thoughtless collecting so often indulged in. Local Societies could do much to prevent this by encouraging a more scientific attitude towards collecting and by insisting upon the fact that the study of the habits and life histories of the living organism in the field and not the accumulation of dead specimens is the work of the true naturalist.

Mrs. Hobson, in responding, said it was the needless collecting that ought to be checked. Referring to Mr. Gray's remarks, she said that the bird mentioned was the Red-throated Diver, which had laid its eggs for more than twenty years in Donegal, only to be taken and sold to collectors; but, thanks partly to the Belfast Naturalists' Field Club, a sum of money had been spent in watching, and for once the eggs had been saved from destruction.

The Report of the Corresponding Societies Committee was distributed by the Secretary, and it was decided to apply for a grant of 25*l*.

Second Meeting, September 8.

The Meeting was presided over by Professor Grenville A. J. Cole, Vice-Chairman.

The Corresponding Societies Committee was represented by the Rev. J. O. Bevan, Sir Edward Brabrook, Mr. J. Hopkinson, Mr. W. P. D. Stebbing, and Mr. W. Whitaker.

The Vice-Chairman apologised for the absence of Professor Miers (who was unable, to his great regret, to be present), and in his name welcomed the delegates to the second session.

Professor G. H. Carpenter introduced the following subject:—

On Detailed Natural History Surveys of Restricted Areas, an important work suitable for Local Societies.

He spoke of the advantages to be derived from a survey of the flora and fauna of restricted areas. He described the researches lately carried out in Lambay, a small island off the coast of co. Dublin, described in the 'Irish Naturalist' for January and February 1907. Five animals new to science and twelve additions to the Britannic fauna are among the results of this survey, which threw much light on the immigrations of animals and plants on the east coast of Ireland. At present the North Bull, a grass-covered sandbank in Dublin Bay, known to be less than a century old is being explored in the same way by the Dublin Naturalists' Field Club. It is hoped that this work will enable the course and order of immigration into new areas to be traced. Next year a survey of Clare Island, off the coast of co. Mayo, is to be begun. He urged the importance of the study of such restricted areas in other districts, as likely to help in the solution of geographical problems.

With regard to his use of the word 'Britannic,' he suggested that it should be used when referring to work relating both to Great Britain and to Ireland, the word British being used when speaking only of the former.

Dr. G. H. Pethybridge (President Dublin Naturalists' Field Club) desired to call attention to the exhibition of photographs illustrating local Natural History and Archæology, which that Club had organised for the benefit of members of the British Association visiting Dublin. Included in the collection were several photographs illustrating some of the points referred to by Professor Carpenter in his remarks on the natural history survey of Lambay Island and of the North Bull.

Mr. R. C. Millar (Edinburgh Geological Society) said that in Edinburgh, on the suggestion of Sir John Murray, the Scottish Natural History Society has made arrangements for obtaining, classifying, and keeping up to date a systematic record of information acquired and observations made regarding the physical features, flora and fauna, of the Forth Valley. Field's Catalogue is subscribed for, and the Society stores the cards containing the information and observations in a card cabinet, Dewey's Decimal Tables being used as a convenient index for arranging them.

Mr. F. A. Bellamy (Ashmolean Natural History Society of Oxfordshire) mentioned the great interest obtained from the study of the flora and fauna of an area which he was investigating.

Mr. Frederick Long (Norfolk and Norwich Naturalists' Society) called attention to the fact that a few years ago Mr. Robert Gurney established a small laboratory on Sutton Broad, in Norfolk, for the use of anyone wishing to prosecute research work. Mr. Balfour Browne worked there for some time, chiefly on the Mollusca of the Broads. A lady at the present time is working at the flora of the district. Board and lodging are provided at the laboratory for 30*s.* a week. While staying there Mr. Browne made a map of the district, marked out in squares for convenience in noting localities.

Professor Carpenter, in reply, spoke as to what it was proposed to do in the investigation of Clare Island.

Mr. Henry Davey (Brighton and Hove Natural History and Philosophical Society) brought forward his paper—

The Advisability of Re-stocking Haunts whence Fauna and Flora have Disappeared.

This paper having been printed in the 'Brighton and Hove N. H. and Phil. Soc.'s Ann. Report for 1908,' pp. 28–31, a short abstract only is now given.

The author, having shown that the problem is less simple than appears and that the larger Mammalia are most in danger of extinction, while the more beautiful and rare birds also require protection, turns to the Lepidoptera for a detailed exposition of his views. Here he makes it clear that, besides man's attacks, various actions of Nature are involved in the uncertainty of the occurrence of various species, and that while for some inexplicable reason a species will disappear for years, it suddenly will reappear in great abundance. He deals especially with the Large Copper, the Clouded Yellow, the Pale Clouded Yellow, and the Large Blue butterflies. He shows that the profusion or rarity of these species is greatly influenced by natural causes, and, speaking of the Large Blue and Mr. Frohawk's discoveries in 1903 in Cornwall, points out that the life-history of many insects is still only partly known. Nevertheless, he advocates the re-stocking and protection of rare animals and plants. The task, however, should be undertaken in a scientific spirit, and allowance made for a certain proportion of failures.

Professor Carpenter (Dublin) said that the main point to remember in any scheme of preservation or introduction of rare forms was that those species which tended to become extinct were usually of commercial value.

Mr. W. P. D. Stebbing mentioned how very often valuable work could be done in the distribution of beautiful plants and insects when they were becoming scarce through increasing cultivation of some of their areas. He particularly instanced what had been done this last season by Mr. Henry Preston (Lincolnshire Naturalists' Union) in collecting the caterpillars of the Peacock butterfly, which was becoming scarce in his part of the county through the ruthless destruction of nettles, in keeping them through the larval and chrysalis states till they emerged as perfect insects, and then setting them free in areas less likely to be disturbed.

Mr. Davey in his reply said that he thought when desirable Continental species would thrive in this country they should be introduced in spite of Professor Cole's objection that it would nullify much of the work on the distribution of the species. As an example of the recent destruction of interesting forms he mentioned a case where pheasants were lately introduced into woods where they had never been preserved before, and the consequent loss in a short time of much of the district's more valuable fauna and flora.

The Rev. J. O. Bevan (Woolhope Naturalists' Field Club), after a short discussion, brought forward the following resolution: 'That this Conference of Delegates of Corresponding Societies affirms the desirability of bringing under the notice of Local Societies the necessity for preserving the fauna and flora of their respective districts as against wanton destruction or careless and needless collecting.'

Mrs. Hobson (Belfast Naturalists' Field Club), in seconding the proposal, reiterated the uselessness of the ordinary collection of stuffed birds and such things. The only way to prevent this kind of destruction was to influence public opinion.

The resolution was carried unanimously.

Mr. F. A. Bellamy (Ashmolean Natural History Society of Oxfordshire), who exhibited his method for the permanent recording of Natural History or other observations by means of the Card Catalogue System, spoke as to the great value to workers of such a catalogue, but said that care was needed in outlining such a scheme that it would retain its usefulness whatever the size. In a paper which he had had printed, and which was distributed to the members, he analysed the aims and methods of natural history societies, and the large amount of time spent with very little result. He then gave a summary of the progress and the future scheme of work arranged for his society, and finally submitted estimates of the initial cost of the tray, cover, and cards as exhibited, and the general arrangement of the Mollusca Card Catalogue.

The Corresponding Societies of the British Association for 1908–1909.

Affiliated Societies.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Technical College, Glasgow. R. Barnett Johnstone and George Lunam	330	None	2s. 6d.	Annals, occasionally.
Ashmolean Natural History Society of Oxfordshire, 1828	F. A. Bellamy, M.A., 4 St. John's Road, Oxford	347	None	5s.	Report, annually.
Bath Natural History and Antiquarian Field Club, 1855	J. Langfield Ward, Royal Literary and Scientific Institution, Bath	50	5s.	10s.	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Museum, College Square. R. M. Young, M.R.I.A.	210	None	1l. 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Museum, College Square. R. Welch, M.R.I.A., and Miss Jean Agnew	420	5s.	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Rev. J. J. M. L. Aiken, B.D., Manse of Ayton, Berwickshire	400	10s.	8s. 6d.	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Alfred Cresswell, Birmingham and Midland Institute, Paradise Street, Birmingham	132	None	10s. 6d. and 5s.	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Avebury House, Newhall Street, Birmingham. W. B. Grove, M.A., and F. J. Brown	185	None	1l. 1s.	Proceedings, occasionally.
Brighton and Hove Natural History and Philosophical Society, 1854	J. Colbatch Clark, 9 Marlborough Place, Brighton	160	None	10s.	Report, annually.
Bristol Naturalists' Society, 1862	J. H. Priestley, B.Sc., University College, Bristol	158	5s.	10s. and 5s.	Proceedings, annually.
British Mycological Society, 1896	Carleton Rea, 34 Foregate Street, Worcester	87	None	10s.	Transactions, annually.
Buchan Field Club, 1887	J. F. Tocher, B Sc., Chapel Street, Peterhead	170	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	H. Lloyd Hind, B.Sc., Ravenscliff, Stapenhill, Burton-on-Trent	200	None	5s.	Report, annually; Transactions, occasionally.
Canada, Royal Astronomical Society of, 1884	Canadian Institute Building, Toronto. J. R. Collins	500	None	2 dollars	Journal, bi-monthly.
Caradoc and Severn Valley Field Club, 1893	H. E. Forrest, 37 Castle Street, Shrewsbury	207	5s.	5s.	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	W. Gilbert Scott, 25 Duke Street, Cardiff	400	None	12s. 6d.	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Grosvenor Museum, Chester. G. P. Miln and F. Simpson	1,040	None	5s. and 2s. 6d.	Report and Proceedings, annually.
Cornwall, Royal Geological Society of, 1814	The Museum, Public Buildings, Penzance. John B. Cornish	98	None	1l. 1s.	Transactions, annually.
Cornwall Royal Polytechnic Society, 1833	E. W. Newton, Camborne, Cornwall	388	None	10s. upwards	Report, annually.
Croydon Natural History and Scientific Society, 1870	Public Hall, Croydon. G. W. Moore	170	None	10s., 5s., and 2s. 6d.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Rev. Herbert Pentin, M.A., M.R.A.S., Milton Abbey Vicarage, Dorset	400	10s.	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	J. de W. Hinch, National Library of Ireland, Dublin, and J. Bayley Butler, M.A.	132	Memb. 5s.; Assoc. none	Members 5s.; Associates 2s. 6d.	'Irish Naturalist,' monthly; Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	S. Arnott, Sunnymead, Dumfries	250	None	5s.	Transactions and Proceedings, annually

East Kent Scientific and Natural History Society, 1857	A. Lander, The Medical Hall, Canterbury	97	None	10s. and 5s.	Transactions, annually.
Eastbourne Natural History Society, 1867	Henry Sparks, Villa Ruhe, 5 St. Leonard's Road, Eastbourne	71	2s. 6d.	7s. 6d.	Transactions, biennially.
Edinburgh Field Naturalists' and Microscopical Society, 1869	John Thomson, 21 St. Ninian's Terrace, Edinburgh	220	5s.	5s.	Transactions, annually.
Edinburgh Geological Society, 1834	India Buildings, Edinburgh. David Gloag	239	10s. 6d.	12s. 6d.	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	Norris Mackay, W.S., Elgin	196	None	5s.	Transactions, occasionally.
Essex Field Club, 1880	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	Peter Macnair, F.R.S.E., 207 Bath Street, Glasgow	300	None	10s.	Transactions and Proceedings, annually.
Glasgow, Natural History Society of, 1851	Alex. Ross, 409 Great Western Road, Glasgow	273	None	7s. 6d.	Transactions and Proceedings, annually.
Glasgow, Royal Philosophical Society of, 1802	Prof. Peter Bennett, 207 Bath Street, Glasgow	1,000	1l. 1s.	1l. 1s.	Proceedings, annually.
Halifax Scientific Society, 1874	F. Barker, 11 Hall Street, Halifax	151	None	2s. 6d.	——
Hampshire Field Club and Archæological Society, 1885	W. Dale, F.S.A., F.G.S., The Lawn, Archer's Road, Southampton	250	None	7s. 6d.	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	A. E. Gibbs, F.L.S., St. Albans, and A. Sutton, Watford	160	10s.	10s.	Transactions, twice a year.
Holmesdale Natural History Club, 1857	Miss M. C. Crosfield, Undercroft, Reigate	90	None	10s. and 5s.	Proceedings, every two or three years.
Hull Geological Society, 1887	J. W. Stather, F.G.S., Newland Park, Hull	72	None	5s.	Transactions, annually.
Hull Scientific and Field Naturalists' Club, 1886	T. Stainforth, The Museum, Hull	142	None	5s.	Transactions, annually.
Institution of Mining Engineers, 1889	Percy Strzelecki, Neville Hall, Newcastle-upon-Tyne	3,300	None	None	Transactions, monthly.
Ireland, Statistical and Social Inquiry Society of, 1847	W. Lawson, Dr. N. M. Falkiner, and C. H. Oldham, 35 Molesworth Street, Dublin	100	None	1l.	Journal, annually.
Leeds Geological Association, 1873	E. Hawkesworth, Crossgates, Leeds	112	None	5s.	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Corporation Museum. W. A. Evans, 24 Fosse Road South, Leicester	350 Membs. & Associates	None	Members 1l. 1s.; Associates 10s. 6d.	Transactions, half-yearly.
Lincolnshire Naturalists' Union, 1893	Arthur Smith, F.L.S., City and County Museum, Lincoln	110	None	5s.	Transactions, annually.
Liverpool Biological Society, 1886	J. A. Clubb, M.Sc., Free Public Museum, Liverpool	95	10s. 6d. and 2s. 6d.	1l. 1s. and 10s. 6d.	Proceedings and Transactions, annually.
Liverpool Engineering Society, 1875	T. R. Wilton, B.A., Royal Institution, Liverpool	550	None	1l. 1s. and 10s. 6d.	Transactions and Report, annually.
Liverpool Geographical Society, 1891	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Buildings, Liverpool	590	None	Members 1l. 1s.; Associates 10s. 6d.	Transactions and Report, annually.
Liverpool Geological Society, 1858	Royal Institution. W. A. Whitehead, B.Sc.	70	None	1l. 1s. and 10s. 6d.	Proceedings, annually.
London: Quekett Microscopical Club, 1865	W. B. Stokes, 4 Winn Road, Lee, S.E.	462	None	10s.	Journal, half-yearly.
London: Selborne Society, 1885	20 Hanover Square, W. W. M. Webb, F.L.S.	2,020	None	5s.	Nature Notes, monthly.
Man, Isle of, Natural History and Antiquarian Society, 1879	P. M. C. Kermode, Claghbane, Ramsey, Isle of Man	150	2s. 6d.	7s. 6d. and 5s.	Proceedings, three times a year; Transactions, occasionally.
Manchester Geographical Society, 1884	F. Zimmern and J. Howard Reed, 16 St. Mary's Parsonage, Manchester	650	None	Members 1l. 1s.; Associates 10s. 6d.	Journal, quarterly.
Manchester Geological and Mining Society, 1838	5 John Dalton Street, Manchester. Sydney A. Smith	300	None	2l. 2s., 1l. 5s., 1l. 1s., and 1l.	Transactions of Inst. of Mining Engineers, monthly

Affiliated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Manchester Microscopical Society, 1880	Frederick Dishley, 14 Westwood Street, Moss Side, Manchester	217	5*s.*	6*s.*	Transactions and Report, annually.
Manchester Statistical Society, 1833	Theodore Gregory, 3 York Street, Manchester	191	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	E. Meyrick, F.R.S., Marlborough College	280	1*s.* 6*d.*	3*s.* and 5*s.*	Report, annually.
Midland Counties Institution of Engineers, 1871	G. Alfred Lewis, M.A., Albert Street, Derby	420 Membs., Associates & Students	1*l.* 1*s.* None	Members 31*s.* 6*d.*; Associates and Students 20*s.*	Transactions of Institution of Mining Engineers, monthly.
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	L. T. O'Shea, The University, Sheffield	306	None	1*l.* 10*s.*	Transactions of Inst. of Mining Engineers, monthly.
Norfolk and Norwich Naturalists' Society, 1869	W. A. Nicholson, 51 Surrey Street, Norwich	284	None	6*s.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	Neville Hall, Newcastle-upon-Tyne	1,350	None	25*s.* and 42*s.*	Transactions of Inst. of Mining Engineers, monthly.
North Staffordshire Field Club, 1865	W. Wells Bladen, Stone, Staffs	522	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	H. N. Dixon, M.A., 23 East Park Parade, Northampton	210	None	10*s.*	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829	Hancock Museum, Newcastle-on-Tyne. N. H. Martin, F.L.S., and C. E. Robson	430	None	21*s.*	Transactions, annually.
Nottingham Naturalists' Society, 1852	Prof. J. W. Carr, M.A., University College, Nottingham	184	2*s.* 6*d.*	5*s.*	Report and Transactions, annually.
Paisley Philosophical Institution, 1808	J. Gardner, 3 County Place, Paisley	578	5*s.*	7*s.* 6*d.*	Report and Meteorological Observations, annually.
Perthshire Society of Natural Science, 1867	Tay Street, Perth. S. T. Ellison	382	2*s.* 6*d.*	5*s.* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	J. Reginald Ashworth, D.Sc., 105 Freehold Street, Rochdale	244	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878	John Hepworth, Linden House, Rochester	173	None	5*s.*	'Rochester Naturalist,' quarterly.
Somersetshire Archæological and Natural History Society, 1849	The Castle, Taunton. Rev. F. W. Weaver, Rev. E. H. Bates, and C. Tite	693	10*s.* 6*d.*	10*s.* 6*d.*	Proceedings, annually.
South African Philosophical Society, 1877	G. M. Clark, South African Museum, Cape Town	207	None	2*l.*	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	Rev. R. Ashington Bullen, B.A., Englemoor, Heathside Road, Woking	53 Societies	None	Minimum 5*s.*	'South-Eastern Naturalist,' annually.
Southport Literary and Philosophical Society	Arthur Quayle, 2 Post Office Avenue, Southport	120	None	7*s.* 6*d.*	Proceedings, annually.
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	G. D. Smith, 3 Newhall Street, Birmingham	157	1*l.* 1*s.* and 10*s.* 6*d.*	31*s.* 6*d.* and 21*s.*	Transactions of Institution of Mining Engineers, monthly.
Tyneside Geographical Society, 1887	Geographical Institute, St. Mary's Place, Newcastle-on-Tyne. Herbert Shaw, B.A., F.R.G.S.	1,000	None	10*s.*	Journal, annually.

Vale of Derwent Naturalists' Field Club, 1887	**J. E. Patterson, Mossgiel, Rowlands Gill, R.S.O.**	**143**	**None**	**2s. 6d.**	**Transactions, occasionally.**
Warwickshire Naturalists' and Archæologists' Field Club, 1854	**Museum, Warwick. O. West, Cross Cheaping, Coventry**	**70**	**2s. 6d.**	**5s.**	**Proceedings, annually.**
Woolhope Naturalists' Field Club, 1851	**Woolhope Club Room, Free Library, Hereford. H. Cecil Moore**	**250**	**10s.**	**10s.**	**Transactions, biennially.**
Worcestershire Naturalists' Club, 1847	**Education Offices, Worcester, F. T. Spackman, F.G.S.**	**109**	**10s.**	**5s.**	**Transactions, annually.**
Yorkshire Geological Society, 1837	**Rev. W. Lower Carter and Cosmo Johns, Burngrove, Pittmoor Road, Sheffield.**	**219**	**None**	**13s.**	**Proceedings, annually.**
Yorkshire Naturalists' Union, 1861	**The Museum, Hull. T. Sheppard, F.G.S.**	**491 and 3,336 Associates**	**None**	**10s. 6d.**	**Transactions, annually; 'The Naturalist,' monthly.**
Yorkshire Philosophical Society, 1822	**Museum, York. Dr. Tempest Anderson and C. E. Elmhirst.**	**480**	**None**	**2l.**	**Report, annually.**

Associated Societies.

Bakewell Naturalists' Club, 1896	W. Storrs Fox, M.A., F.Z.S., St. Anselm's, Bakewell	55	None	5s. and 2s. 6d.	—
Balham and District Antiquarian and Natural History Society, 1897	A. L. Barron, Clophill, Wallington, Surrey	68	None	5s.	Papers, occasionally.
Barrow Naturalists' Field Club and Literary and Scientific Association, 1876	Cambridge Hall, Strand, Barrow. W. L. Page, 5 Cavendish Street	335	None	5s. and 2s. 6d.	Report and Proceedings, &c., annually.
Battersea Field Club, 1894	Public Library, Lavender Hill, Battersea, S.W. Everard J. Davies	50	None	3s. 6d.	—
Bournemouth Natural Science Society, 1903	Dr. J. R. L. Dixon, Sherbrook, Christchurch Road, Bournemouth	250	None	5s.	Report, annually.
Bradford Natural History and Microscopical Society, 1875	Fred. Jowett, Vincent Street, Bradford	95	1s.	4s.	Report, annually.
Bradford Scientific Association, 1875	Rosse Butterfield, Bank House, Wilsden, Bradford	300	None	5s. and 2s. 6d.	Bradford Scientific Journal, quarterly.
Catford and District Natural History Society, 1897	W. H. Griffin, 40 Blythe Vale, Catford, S.E.	80	1s.	3s.	—
Dover Sciences Society, 1879	Percy Moring, 23 Randolph Gardens, Dover	62	None	6s.	Reports, annually; Leaflets, occasionally.
Dunfermline Naturalists' Society, 1902	Robert Somerville, B.Sc., 82 James Street, Dunfermline	183	None	5s.	—
Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, 133 The Grove, Ealing, W.	125	None	10s. and 2s. 6d.	Report and Transactions, annually.
Grimsby and District Antiquarian and Naturalists' Society, 1896	The Museum, Grimsby. Dr. G. A. Grierson	102	None	4s.	—
Hampstead Scientific Society, 1899	C. O. Bartrum, B.Sc., and R. W. Wylie, M.A., 12 Heath Mansions, Heath Street, Hampstead, N.W.	286	None	Minimum 5s.	Report and Proceedings, annually.
Haslemere Natural History Society, 1888	F. A. Oldaker, The Red House, Haslemere	86	None	Minimum 2s.	Report, annually; Science Papers, occasionally.
Hastings and St. Leonards Natural History Society, 1893	Corporation Museum, Brassey Institute, Hastings. W. Ruskin Butterfield	450	1s.	2s. 6d.	'Hastings and East Sussex Naturalist,' half-yearly.

Associated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Hawick Archæological Society, 1856	J. J. Vernon, 81 High Street, Hawick	250	None	2*s.* 6*d.*	Transactions annually.
Inverness Scientific Society and Field Club, 1875	W. J. Watson, Royal Academy, Inverness	197	None	5*s.*	Transactions, occasionally.
Ipswich and District Field Club, 1903	Charles B. White, 19 Salisbury Road, Ipswich	170	None	1*s.*	—
Lancashire and Cheshire Entomological Society, 1877	Royal Institution, Liverpool. H. R. Sweeting, M.A.	140	None	5*s.*	Report and Proceedings, annually.
Leeds Naturalists' Club and Scientific Association, 1868	J. Digby Firth, F.L.S., 22 Burchett Place, Delph Lane, Leeds	83	None	6*s.*	Transactions, occasionally.
Lewisham Antiquarian Society, 1885	J. W. Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S.E.	120	None	5*s.*	Transactions, occasionally.
Liverpool Microscopical Society, 1866	Royal Institution, Liverpool. W. T. Haydon	65	10*s.* 6*d.*	10*s.* 6*d.*	Report, annually.
Liverpool Science Students' Association, 1881	Royal Institution, Liverpool. H. W. Greenwood	48	2*s.* 6*d.*	5*s.*	—
London: City of London Entomological and Natural History Society, 1858	The London Institution, Finsbury Circus, E.C. T. H. L. Grosvenor.	79	2*s.* 6*d.*	7*s.* 6*d.*	Transactions, annually.
London: North London Natural History Society, 1892	R. W. Robbins, Tonah, Falmouth Avenue, Hale End, Chingford	101	2*s.* 6*d.*	5*s.* and 2*s.* 6*d.*	Report, annually.
London: South London Entomological and Natural History Society, 1872	Hibernia Chambers, London Bridge, S.E. Stanley Edwards, F.L.S.	170	2*s.* 6*d.*	7*s.* 6*d.*	Proceedings, annually.
Maidstone and Mid-Kent Natural History Society, 1868	Maidstone Museum. A. Barton and J. W. Bridge	109	None	10*s.* and 5*s.*	Report, triennially.
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1793	Newcastle-upon-Tyne. Alfred Holmes and Frederick Emley	2,800	None	1*l.* 1*s.*	—
Penzance Natural History and Antiquarian Society, 1839	Public Buildings, Penzance. J. B. Cornish	50	None	10*s.* 6*d.*	Transactions, occasionally.
Preston Scientific Society, 1893	Lecture Hall, 119A Fishergate, Preston. W. Hy. Heathcote	598	None	5*s.*	Papers, occasionally.
Scarborough Philosophical and Archæological Society, 1828	The Museum, Scarborough. Herbert King, M.Sc.	101	None	1*l.* and 10*s.*	Report, annually.
School Nature Study Union, 1903	H. E. Turner, 1 Grosvenor Park, Camberwell, S.E.	1,000	None	2*s.* 6*d.*	'School Nature Study,' three times a year; Leaflets, occasionally.
Scottish Microscopical Society, 1888	Philosophical Institution, 4 Queen Street, Edinburgh. Dr. W. G. Robertson	60	None	10*s.* 6*d.*	Proceedings, annually.
Southport Society of Natural Science, 1890	George Cross, Shaftesbury Buildings, Eastbank Street, Southport	268	None	5*s.*	Report, annually.
Teign Naturalists' Field Club, 1858	John S. Amery, Druid, Ashburton, Devon	120	None	2*s.* 6*d.*	Report, annually.
Torquay Natural History Society, 1844	Alex. Somervail, The Museum, Torquay	209	10*s.* 6*d.*	1*l.* 1*s.*	—
Tunbridge Wells Natural History and Philosophical Society, 1884	R. R. Hutchinson, 28 Princes Street, Tunbridge Wells	154	None	10*s.* 6*d.*, 5*s.*, and 3*s.* 6*d.*	Report, annually.
Warrington Field Club, 1884	Alf. J. Jolley, 16 Arpley Street, Warrington	53	None	2*s.*	—
Watford Camera Club, 1902	W. Branch, 100 High Street, Watford	75	None	10*s.* and 5*s.*	—

Catalogue of the more important Papers, especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1908.

*** 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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Section B.—CHEMISTRY.

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TRANSACTIONS OF THE SECTIONS.

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Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section.—W. N. Shaw, Sc.D., LL.D., F.R.S.

THURSDAY, SEPTEMBER 2.

The President delivered the following Address:—

It is with much misgiving that I endeavour to discharge the traditional duty of the President of a Section of the British Association. So many other duties seem to find a natural resting-place with anyone who has to reckon at the same time with the immediate requirements of the public, the claims of scientific opinion, and the interests of posterity, that, unless you are content with such contribution towards the advancement of the sciences of mathematics and physics as my daily experience enables me to offer you, I shall find the task impossible.

With a leaning towards periodicity perhaps slightly unorthodox I have looked back to see what they were doing in Section A fifty years ago. Richard Owen was President of the Association, William Whewell was President of Section A for the fifth time.

At the meeting of 1858 they must have spent some time over nineteen very substantial reports on researches in science, which included a large section of Mallett's facts and theory of earthquake phenomena, magnetic surveys of Great Britain and of Ireland, and, oddly enough, an account of the self-recording anemometer by Beckley; perhaps a longer time was required for fifty-seven papers contributed to the Section, but very little was spent over the Presidential Address, for it only occupies two pages of print. My inclination towards periodicities and another consideration leads me to regard the precedent as a good one. That other consideration is that Section A has always more subjects for discussion than it can properly dispose of; and, in this case, discipline, like charity, might begin at home.

Since the Section met last year it has lost its most illustrious member and its most faithful friend. Lord Kelvin made his first contribution to Section A at Cambridge in 1845, on the elementary laws of statical electricity; he was President of the Section in 1852 at Belfast for the first of five times. I have looked to see what suggestion I could derive from his first essay in that capacity. I can find no reference to any Address in the published volume. I wish I had the courage to follow that great example.

Lord Kelvin's association with Section A was so constant and so intimate that it requires more than a passing word of reference. There is probably no student of Mathematics or Physics grown into a position of responsibility in this country but keeps among his treasured reminiscences some words of inspiration and of encouragement from Kelvin, spoken in the surroundings which we are once more met to inaugurate. I refer to those unrecorded acts of kindness and help because they were really a striking characteristic of Section A. Their value for the amenity as well as for the advancement of science it would be difficult to overestimate. I could not, even if time permitted, hope to set before you an adequate appreciation of Kelvin's contributions to Science as illustrated by his communications to this Section, and in this place it is not necessary. But I cannot pass over that feature of his character without notice.

Closely following on the loss of Kelvin came the death of Sir Richard Strachey, a personal loss to which it is difficult to give expression. I am not aware that he had much to do with Section A. I wish, indeed, that the Section had seen its way to bring him more closely into touch with its proceedings. He was President of Section E in 1875, and, by appointment of the Royal Society, he was for twenty-two years Chairman of the Meteorological Council. I had the good fortune to be very closely associated with him during the last ten years of his life, and to realise the ideas which lay behind his official actions and to appreciate the reality of his services to science in the past and for the future.

These losses unfortunately do not stand alone. Only last year Sir John Eliot received the congratulations of all his fellow-workers upon the publication of his Climatological Atlas of India as representing the most conspicuous achievement of orderly, deliberate, purposeful compilation of meteorological facts for a special area that has yet been seen. He was full of projects for a handbook to accompany the atlas, and of ideas for the prosecution of meteorological research over wide areas by collecting information from all the world and enlisting the active co-operation of the constituent parts of the British Empire in using those observations for the advancement of science and the benefit of mankind. He died quite suddenly on March 18, not young as years go, but quite youthful in the deliberate purpose of manifold scientific activities and in his irrepressible faith in the future of the science which he has adorned.

The Section will, I hope, forgive me if I put before them some considerations which the careers of these three men suggest. Kelvin, a mathematician, a natural philosopher, a University Professor, some part of whose scientific work is known to each one of us. He was possessed with the notion that Mathematics and Natural Philosophy are applicable in every part of the work of daily life, and made good the contention by presenting to the world, besides innumerable theoretical papers, instruments of all degrees of complexity, from the harmonic analyser to an improved water-tap. It was he who transfigured and transformed the mariner's compass and the lead-line into instruments which have been of the greatest practical service. It was he who, when experimental science was merely a collection of facts or generalisations, conceived the idea of transfiguring every branch of it by the application of the principles of natural philosophy, as Newton had transfigured astronomy. The ambition of Thomson and Tait's 'Natural Philosophy,' of which only the first volume reached the stage of publication, is a fair index of Kelvin's genius.

Strachey, on the other hand, by profession a military engineer, a great administrator, head of the Public Works Department in India, deeply versed in finance and in all the other constituent parts of administration, by his own natural instinct demanded the assistance of science for every branch of administration. In promoting the development of botany, of meteorology, of geodesy, and of mathematics, he was not administering the patronage of a Maecenas, but claiming the practical service of science in forestry, in agriculture, in famine relief, in public works, and in finance. You cannot gauge Strachey's services to science by the papers which he contributed to scientific societies, if you leave out of account the fact that they were really incidents in the opening of fresh channels of communication between scientific work and the public service.

And Eliot, as Meteorological Reporter to the Government of India, an accomplished mathematician (for he was second wrangler and first Smith's prizeman in 1869), a capable and devoted public servant, the medium by which Strachey's ideas as regards the use of meteorology in administration found expression in the Government of India, who caught the true perception of the place of science in the service of the State, and made his office the indispensable handmaid of the Indian administration. These three men together, who have all passed away within a space of three months, are such representative types of scientific workers, complementary and supplementary that a similar combination is not likely to occur again. All three indispensable, yet no two alike, except in their enthusiasm for the sciences for the advancement of which Section A exists.

To these I might indeed add another type, the private contributor to the physical exploration of the visible universe, of which Ireland furnishes so many noble examples; and in that connection let me give expression to the sense of grievous loss, to this Association and to Science, occasioned by the premature death of W. E. Wilson, of Daramona, a splendid example of that type.

[When the preceding paragraph was written I was mindful of special obligations, official and personal, to Birr Castle, and I must be allowed to associate myself and the Section with all that was said at the opening meeting about the late Earl of Rosse.]

In the division of the work of advancing the sciences of mathematics and physics and their application to the service of mankind, I am reminded of Dryden's somewhat lopsided comparison of the relative influence of music and song in his Ode to St. Cecilia's Day. If I may be pardoned for comparing small things with great, the power of Timotheus' music over Alexander's moods was hardly less complete than Kelvin's power to touch every department of the working world with his genius. But I may remind you that, after a prolonged description of the tremendous influence of Timotheus upon the victorious hero, the poet deals in one stanza with his nominal subject:—

> 'At last divine Cecilia came,
> Inventress of the vocal frame;
> The sweet enthusiast, from her sacred store,
> Enlarged the former narrow bounds
> . . . .
> With nature's mother-wit, and arts unknown before.
>
> Let old Timotheus yield the prize,
> Or both divide the crown;
> He raised a mortal to the skies,
> She drew an angel down.'

I doubt if any of my hearers who knew Strachey by sight would recognise in him the scientific reincarnation of St. Cecilia, but it is none the less true that he was pre-eminent among men in inventing the means of drawing angels down and using their service for the attuning of common life to a scientific standard. It may be equally hard for those who knew him to look upon Eliot as a vocal frame, for of all his physical capacities his voice was the least impressive; and yet it is not untrue to say that he was conspicuously a medium by which the celestial harmonies of the physical sciences were brought into touch with the practical life of India through his work, which is represented by a considerable number of the twenty volumes of Memoirs of the Indian Meteorological Service.

I do not indulge in this poetic extravagance without some underlying reason. Speaking for the physics of the atmosphere, there is a real distinction between these three sides of scientific work. To some is given the power of the mathematician or the physicist to raise the mortal to the skies, to solve some problem which, if not in itself a meteorological one, still has a bearing, sooner or later to be discovered and developed, upon the working of atmospheric phenomena. It is easy enough to cite illustrious examples: among notable instances there recur to my mind Rayleigh's work on the colour of the sky and Pernter's meteorological optics; papers by Ferrel and others on the general circulation of the atmosphere; Kelvin and Rayleigh on the elastic oscillations of the atmosphere; the papers by Hagen, Helmholtz, Oberbeck, Margules, Hertz, and Von Bezold on the dynamics and thermodynamics of the atmosphere, collected and translated by Cleveland Abbé; the work on atmospheric absorption by Langley and the theoretical papers on radiation by Poynting; those on condensation nuclei by Aitken and C. T. R. Wilson, and the recent work on atmospheric electricity, including the remarkable paper by Wilson on the quiet transference of electricity from the air to the ground.

But these things are not of themselves applied to the meteorology of everyday life. It is, in a way, a separate sense, given to few, to realise the possibilities that may result from the solution of new theoretical problems, from the invention of new methods—to grasp, in fact, the idea of bringing the angels down. And, in order that the regular workers in such matters may be in a position constantly to reap the advantages which men of genius provide, the vocal frame must have its permanent embodiment. For the advancement of science in this sense we require all three—the professor with academic freedom to illuminate with his genius any phenomenon which he may be pleased to investigate, the administrator, face to face with the practical problems in which science can help, and the living voice which can tune itself in harmony with the advances of science and in sympathy with the needs of the people whom it serves.

The true relations of these matters are not always apparent. Eliot, bringing to the work of the Indian Meteorological Office a mind trained in the mathematical school of which Kelvin was a most conspicuous exponent, achieved a remarkable success, with which perhaps my hearers are not familiar.

In this country there is a widespread idea that meteorology achieves its object if by its means the daily papers can give such trustworthy advice as will enable a cautious man to decide whether to take out his walking-stick or his umbrella. Some of us are accustomed to look upon India as a place of unusual scientific enlightenment, where governments have a worthy appreciation of the claims of science for recognition and support. But Eliot was never tired of telling me that it was the administration of India, and not the advancement of science, that the Indian administrators had in view; and among his achievements the one of which he was most proud was that the conduct of his office upon scientific lines during his tenure had so commended itself to the administrators that his successor was to be allowed three assistants, with special scientific training, in order that the State might have the benefit of their knowledge.

It is, of course, easy to suggest in explanation of this success that the Department of Public Works of India cannot afford to be unmindful of the distribution of rainfall, and that there is an obvious connection between Indian finances and Indian droughts; but it is a new fact in British history that the application of scientific considerations to the phenomena of rainfall are of such direct practical importance that meteorological information is a matter of consequence to all Government officials, and that meteorological prospects are a factor of finance. Imagine his Majesty's Chancellor of the Exchequer calling at 63 Victoria Street to make inquiries with a view to framing his next Budget, or taking his prospects of a realised surplus from the Daily Weather Report. Yet in India meteorology is to such an extent a public servant that such proceedings would not excite remark.

To have placed a scientific service on such a footing is, indeed, a notable success. Again, I rely upon Eliot when I say that that success is only to be achieved by being constantly on the watch to render service wherever service can be rendered. There is a difference between this attitude and that which has for its object the contribution of an effective paper to a scientific publication; in other words, it must be frankly recognised that the business of the scientific departments of government is not to raise an occasional mortal to the skies, but to draw down as many angels as are within reach. I was much surprised, when Eliot wished to develop a large scheme for meteorological work on a wider scale, that he made his appeal to the British Association as Chairman of the Sub-section for Cosmical Physics at Cambridge, and thereby to the Governments of this country and the Colonies. He felt that he could only urge the Indian Government to join, and he did so successfully, so far as India would be directly benefited thereby, however important the results might be from a purely scientific point of view. Strange as it may appear to some, it was to this country that he looked for assistance, on the plea of the increase of knowledge for its own sake, or for the sake of mankind at large.

I am disposed, therefore, to carry your thoughts a little further, and rely on your patience while I consider another aspect of the process of drawing down the angels from the mathematical and physical sky, a process which is sufficiently indicative of the functions of a State scientific department. Viewing the world at large, and not merely that part of it with which we are ourselves immediately concerned, such departments deal with celestial physics in astronomy, with the physics of the air in meteorology and atmospheric electricity, with the physics of land and water in physical geography and geology, seismology and terrestrial magnetism, oceanography and hydrography. It is for the practical applications of these sciences to the service of the navigator, the fisherman, the husbandman, the miner, the medical man, the engineer, and the general public that there is an obvious public want.

Let me carry you with me in regarding these departments, primarily, as centres for establishing the growth of science by bringing it to bear upon the practical business of life, by a process of regular plantation, and not the occasional importation of an exotic scientific expert. I shall carry you with me also if I say that the gravest danger to such scientific institutions is the tendency to waste. I use the term 'waste' not in its narrowest but in its most liberal sense, to include waste of money, waste of effort, waste of scientific opportunity. I do not regard it as a waste that such a department should be unable to emulate Timotheus' efforts. Any aspiration in that direction is, of course, worthy of every encouragement, but the environment is not generally suitable for such achievements. I do, however, regard it as waste if the divine Cecilia is not properly honoured, and if advantage is not taken of the fullest and freest use of the newest and best scientific methods, and their application in the widest manner possible.

I speak for the Office with which I am connected when I say its temptations to waste are very numerous and very serious. It is wasteful to collect observations which will never be used; it is equally wasteful to decline to collect observations which in the future may prove to be of vital importance. It is wasteful to discuss observations that are made with inadequate appliances; it is equally wasteful to allow observations to accumulate in useless heaps because you are not sure that the instruments are good enough. It is wasteful to use antiquated methods of computation or discussion; it is equally wasteful to use all the time in making trial of new methods. It is wasteful to make use of researches if they are inaccurate; it is equally wasteful to neglect the results of researches because you have not made up your mind whether they are accurate or not. It is wasteful to work with an inadequate system in such matters as synoptic meteorology; it is equally wasteful to lose heart because you cannot get all the facilities which you feel the occasion demands.

It is the business of those responsible for the administration of such an office to keep a nice balance of adjustment between the different sides of activity, so that in the long run the waste is reduced to a minimum. There must in any case be a good deal of routine work which is drudgery; and if one is to look at all beyond the public requirements and public appreciation of the immediate present, there must be a certain amount of enterprise and consequently a certain amount of speculation.

Let me remark by the way that there is a tendency among some of my meteorological friends to consider that a meteorological establishment can be regarded as alive, and even in good health, if it keeps up its regular output of observations in proper order and up to date, and that initiative in discussing the observations is exclusively the duty of a central office. That is a view that I should like to see changed. I do not wish to sacrifice my own privilege of initiative in meteorological speculation, but I have no wish for a monopoly. To me, I confess, the speculation which may be dignified by the name of meteorological research is the part of the office work which makes the drudgery of routine tolerable. For my part I should like every worker in the Office, no matter how humble his position may be, somehow or other to have the opportunity of realising that he is taking part in the unravelling of the mysteries of the weather; and I do not think that any establishment, or section of an establishment, that depends upon science can be regarded as really alive unless it feels itself in active touch with that speculation which results in the advancement of knowledge. I do not hesitate to apply to other meteorological establishments, and indeed to all scientific institutions that claim an interest in meteorology, the same criterion of life that I apply to my own office. It is contained in the answer to the question, How do you show your interest in the advancement of our knowledge of the atmosphere? The reply that such and such volumes of data and mean values measure the contribution to the stock of knowledge leaves me rather cold and unimpressed.

But to return to the endeavour after the delicate adjustment between speculation and routine, which will reduce the waste of such an institution to a minimum; experience very soon teaches certain rules.

I have said elsewhere that the peculiarity of meteorological work is that an investigator is always dependent upon other people's observations; his own are only applicable in so far as they are compared with those of others. Up to the present time, I have never known anyone take up an investigation that involved a reference to accumulated data, without his being hampered and harassed by uncertainties that might have been resolved if they had been taken in time. I shall give you an example presently, but, in the meantime, experience of that kind is so universal that it has now become with us a primary rule that any data collected shall forthwith be critically examined and so far dealt with as to make sure that they are available for scientific purposes—that is, for the purposes of comparison. A second rule is that as public evidence of the completion of this most important task there shall be at least a line of summary in a published report, or a point on a published map, as a primary representation of the results. Such publication is not to be regarded as the ultimate application of the observations, but it is evidence that the observations are there, and are ready for use.

You will find, if you inquire, that at the Office we have been gradually lining up these troops of meteorological data into due order, with all their buttons on, until, from the commencement of this year, anyone who wishes to do so can hold a general review of the whole meteorological army, in printed order—first order stations, second order stations, rainfall stations, sunshine and wind stations, sea temperatures and other marine observations—on his own study table, within six months of the date of the observations, upon paying to his Majesty's Stationery Office the modest sum of five shillings and sixpence. For all the publications except one the interval between observation and publication is only six weeks, and as that one has overtaken four years of arrears within the last four years, I trust that by the end of this year six weeks will be the full measure of the interval between observation and publication in all departments. This satisfactory state of affairs you owe to the indefatigable care and skill of Captain Hepworth, Mr. Lempfert, and Mr. R. H. Curtis, and the members of the staff of the Office who work under their superintendence. I need say little about corresponding work in connection with the Daily Weather Report, in which Mr. Brodie is my chief assistant, although it has received and is receiving a great deal of attention. The promptitude with which the daily work is dealt with hardly needs remark from me, though I know the difficulties of it as well as anyone. If I spend only one long sentence in mentioning that on July 1, 1908, the morning hour of observation at twenty-seven out of the full number of twenty-nine stations in the British Isles was changed from 8 A.M. to 7 A.M., and the corresponding post-offices, as well as the Meteorological Office, opened at 7.15 A.M., so that we may have a strictly synchronous international system for Western and Central Europe, and thus realise the aspiration of many years, you will not misunderstand me to mean that I estimate the task as an easy one.

The third general rule is that the effectiveness of the data of all kinds, thus collected and ordered, should be tested by the prosecution of some inquiry which makes use of them in summary or in detail. It is here that the stimulating force of speculative inquiry comes in; and it is in the selection and prosecution of these inquiries, which test not only the adequacy and effectiveness of the data collected but also the efficiency of the Office as contributing to the advance of knowledge, that the most serious responsibility falls upon the administrators of Parliamentary funds.

Scientific Shylocks are not the least exacting of the tribe, and there have been times when I have thought I caught the rumination:—

> *Shy.* Three thousand ducats? 'tis a good round sum!
> *Bas.* For the which, as I told you, Antonio shall be bound.

. . . . . .

> *Shy.* Antonio is a good man?
> *Bas.* Have you heard any imputation to the contrary?
> *Shy.* Oh! no, no, no, no. . . . Yet his means are in supposition: he hath an argosy bound to Tripolis, another to the Indies; I understand moreover, upon the Rialto, that he hath a third in Mexico, a fourth for England, and other ventures he hath squandered abroad. But ships are but boards, sailors but men. There is the peril of water, winds, and rocks. . . . Three thousand ducats.

We at the Meteorological Office are very much in Antonio's position. Our means of research are very much in supposition: four observatories and over four hundred stations of one sort or another in the British Isles; an elaborate installation of wind-measuring apparatus at Holyhead; besides other ventures squandered abroad; an anemometer at Gibraltar, another at St. Helena; a sunshine recorder at the Falkland Isles, half a dozen sets of instruments in British New Guinea, and a couple of hundred on the wide sea. The efforts seem so disconnected that the rumination about the ducats is not unnatural.

And you must remember that we lack an inestimable advantage that belongs to a physical laboratory or a school of mathematics, where the question of the equivalent number of ducats does not arise in quite the same way. The relative disadvantage that I speak of is that in an office the allowance for the use of time and material in practice and training disappears. All the world seems to agree that time or money spent on teaching or learning is well spent. In the course of twenty years' experience at a physical laboratory, and in examinations not a few, I have seen $\mathfrak{M}$ and $\mathfrak{H}$ or the wave length of sodium light determined in ways that would earn very few ducats on the principle of payment by results; but, having regard to the psychological effect upon the culprit or the examiner, the question of ducats never came in. Wisely or unwisely public opinion has been educated to regard the psychological effect as of infinite value compared with the immediate result obtained. But in an office the marks that an observer or computer gets for showing that he 'knew how to do it,' when he did not succeed in doing it, do not count towards a 'first class,' and we have to abide by what we do; we cannot rely on what we might have done. Consequently our means in supposition, spread over sea and land, are matters of real solicitude. In such circumstances there might be reason for despondency if one were dependent merely upon one's own ventures and the results achieved thereby. But when one has the advantage of the gradual development of investigations of long standing, it is possible to maintain a show of cheerfulness. When Shylock demands his pound of flesh in the form of an annual report, it is not at all uncommon to find that some argosy that started on its voyage long ago 'hath richly come to harbour suddenly.' There have been quite a number of such happy arrivals within the last few years.

I will refer quite briefly to the interesting relations between the yield of barley and cool summers, or the yield of wheat and dry autumns, and the antecedent yield of eleven years before, which fell out of the body of statistics collected in the Weekly Weather Report since 1878. The accomplished statisticians of the Board of Agriculture have made this work the starting-point for a general investigation of the relation between the weather and the crops, which cannot fail to have important practical bearings.

Let me take another example. For more than a full generation meteorological work has been hampered by the want of a definite understanding as to the real meaning in velocity, or force, of the various points of the scale of wind-estimates laid down in 1805 by Admiral Beaufort for use at sea, and still handed on as an oral tradition. The prolonged inquiry, which goes back really to the report upon the Beckley anemograph already referred to, issued quite unexpectedly in the simple result that the curve

$$p = {\cdot}0105B^3$$

(where p is the force in pounds per square foot, and B the arbitrary Beaufort number) runs practically through nine out of the eleven points on a diagram representing the empirical results of a very elaborate investigation. The empirical determinations upon which it is based are certainly not of the highest order of accuracy; they rely upon two separate investigations besides the statistical comparison, viz., the constant of an anemometer and the relation of wind-velocity to wind-pressure, but no subsequent adjustment of these determinations is at all likely to be outside the limits of an error of an estimate of wind-force; and the equation can be used, quite reasonably, as a substitute for the original specification of the Beaufort scale, a specification that has vanished with the passing of ships of the type by which it was defined. This result, combined with the equation[1] $p = \cdot 003 V^2$, which has been in use in the Office for many years, and has recently been confirmed as sufficiently accurate for all practical purposes by Dr. Stanton at the National Physical Laboratory and Monsieur Eiffel at the Eiffel Tower, places us upon a new plane with regard to the whole subject of wind-measurement and wind-estimation.

Results equally remarkable appear in other lines of investigation. Let me take the relation of observed wind velocity to barometric gradient. You may be aware that in actual experience the observed direction of the wind is more or less along the isobars, with the low pressure on the left of the moving air in the northern hemisphere; and that crowded isobars mean strong winds. Investigations upon this matter go back to the earliest days of the Office.

There can be no doubt that the relation, vague as it sometimes appears to be upon a weather chart, is attributable to the effect of the earth's rotation. In order to bring the observed wind velocity into numerical relation with the pressure-gradient Guldberg and Mohn assumed a coefficient of surface 'friction,' interfering with the steady motion. The introduction of this new quantity, not otherwise determinable, left us in doubt as to how far the relation between wind and pressure distribution, deducible from the assumption of steady motion, could be regarded as a really effective hypothesis for meteorological purposes.

Recent investigations in the Office of the kinematics of the air in travelling storms, carried out with Mr. Lempfert's assistance, have shown that, so far as one can speak of the velocity of wind at all—that is to say, disregarding the transient variations of velocity of short period and dealing with the average hourly velocity, the velocity of the wind in all ordinary circumstances is effectively steady in regard to the accelerating forces to which it is subject. This view is supported by two conclusions which Mr. Gold has formulated in the course of considering the observations of wind velocity in the upper air, obtained in recent investigations with kites. The first conclusion is that the actual velocity of wind in the upper air agrees with the velocity calculated from the pressure distribution to a degree of accuracy which is remarkable, considering the uncertainties of both measurements; and the second conclusion affords a simple, and I believe practically new, explanation upon a dynamical basis of the marked difference between the observed winds in the central portions of cyclones and anti-cyclones respectively, by showing that, on the hypothesis of steady motion, the difference of sign of the effective acceleration, due to curvature of path and to the earth's rotation respectively, leads to quite a small velocity and small gradient as the limiting values of those quantities near anti-cyclonic centres.

This conclusion is so obviously borne out by the facts that we are now practically in a position to go forward with the considerable simplification which results from regarding the steady state of motion in which pressure gradient is balanced by the effective acceleration due to the rotation of the earth and the curvature of the path, as the normal or ordinary state of the atmosphere.

I cannot forbear to add one more instance of an argosy which has richly come to harbour so lately as this summer. You may be aware that Kelvin was of opinion that the method of harmonic analysis was likely to prove a very powerful engine for dealing with the complexities of meteorological phenomena, as it has, in fact, dealt with those of tides. In this view Sir Richard Strachey and the Meteorological Council concurred, and an harmonic analyser was installed in the

[1] In this equation p is expressed, as before, in pounds per square foot, and V in miles per hour.

Office in 1879, but subsequently numerical calculation was used instead. A considerable amount of labour has been spent over the computation of Fourier coefficients. Not many great generalisations have flowed from this method up to the present time. I have no doubt that there is much to be done in the way of classifying temperature conditions, for climatic purposes, by the analysis of the seasonal variations. A beginning was made in a paper which was brought to the notice of the Association at Glasgow. The most striking result of the Fourier analysis we owe to Hann, who has shown that, if we confine our attention to the second Fourier coefficient of the diurnal variation of pressure—that is, to the component of twelve-hour period—we get a variation very marked in intertropical regions, and gradually diminishing poleward in both hemispheres, but synchronous in phase throughout the 360 degrees of a meridian. The maximum occurs along all meridians in turn about 10 A.M. and 10 P.M. local time. This semi-diurnal variation with its regular recurrence is well known to mariners, and we have recently detected it, true to its proper phase, in the observations at the winter quarters of the 'Discovery'; small in amplitude indeed—about a thousandth of an inch of mercury—but certainly identifiable.

The reality of this variation of pressure, common to the whole earth, cannot be doubted, and, so far as it goes, we may represent it (if indeed we may represent pressure differences as differences in vertical heights of atmosphere) as the deformation of a spherical atmosphere into an ellipsoid, with its longest axis in the Equator pointing permanently 30° to the west of the sun. Its shortest axis would also be in the Equator, and its middle axis would be along the polar axis of the earth. Somehow or other this protuberance remains fixed in direction with regard to the sun, while the solid earth revolves beneath it. Whatever may be the cause of this effect, obviously cosmical, and attributable to the sun, at which it indirectly points, its existence has long been recognised, and further investigation only confirms the generalisation. It is now accepted as one of the fundamental general facts of meteorology.

Professor Schuster, for whose absence from this meeting I may venture to express a regret which will be unanimous, has already contributed a paper to the Royal Society pointing out the possible relations between the diurnal variations of pressure and those of terrestrial magnetic force. Going back again to the ubiquity of the application of the relation of pressure and wind, in accordance with the dynamical explanation of Buys Ballot's law, we should expect the effect of a pressure variation that has its counterpart in that of terrestrial magnetism to be traceable also in wind observations.

Mr. J. S. Dines has just given me particulars of the discovery of that effect in the great air-current, the variations of which I have called the pulse of the atmospheric circulation—I mean the south-east Trade Wind, the most persistent atmospheric current in the world. It is difficult as a rule to get observers to pay much attention to that current, because it is so steady; but in 1891 the Meteorological Council set up an anemometer at St. Helena, in the very heart of the current, and we have just got out the results of the hourly tabulations. When the observations for the hours 1 to 24 are grouped separately for months, so as to give the vector resultants for each hour and for each month, it appears that there is a conspicuous semi-diurnal variation in the current, which shows itself as a closed polygon of vector variations from the mean of the day.

The month of April gives the most striking diagram of the twelve. It displays the superposition of two practically complete dodekagons, one a large one, completing its cycle from 5 A.M. to 5 P.M., the other a small one, from 5 P.M. to 5 A.M. The resultant wind for the whole day is very nearly south-east, and practically remains so for all the months of the year, the monthly variation of resultant wind being confined to a change of velocity from about thirteen miles per hour in May to about twenty miles per hour in September.

If, instead of combining the south and east components to form a vector diagram, we plot their variations separately, the semi-diurnal variation in each is plainly marked; and the calculation of its constants shows that its amplitude is about three-quarters of a mile per hour in the south, and rather less in the east component. The latter has its maxima at 10 A.M. and 10 P.M., and the southerly component is about a quarter of a period in advance. Thus, to correspond with the semi-diurnal variation of pressure, there is a semi-diurnal variation in the Trade Wind at St. Helena, which is equivalent to the superposition upon the resultant wind of a velocity-variation of about one mile and a half per hour, passing through its zero value at half-past ten and half-past four, not far from the hours when the extremes of the ellipsoidal deformation of the spherical atmosphere are passing over the locality, together with a change of direction of six degrees towards the southward between eleven o'clock and five, reversed between five o'clock and eleven.[1]

I have only dealt with one month. I believe that when all the results that flow from this simple statement can be put before you, you will agree with me that the argosy which the Meteorological Council sent out in 1891 has indeed richly come to harbour.

Let me digress to say a word in illustration of the principle I laid down that, if one would avoid waste in meteorological work, the observations must be examined forthwith and so far discussed that any ambiguities may be cleared up.

After some years of wear at St. Helena the persistent rubbing of the south-east part of the spiral metallic pencil upon the metallic paper wore away the metal and left a flat place. This got so bad that the instrument had to come home for repairs, and when it was set up again, after a year's absence, the average direction of the Trade Wind differed by two points from the averages of most, but not of all, of the previous years. So far as we know, the orientation has been attended to, as before, and yet it is hardly possible to resist the suggestion that the anemometer has been set slightly differently. We are now making very careful inquiries from the observer; but, in the meantime, it seems to me that there is a great opportunity for a competent mathematical physicist to help us. Dynamical explanations of the Trade Winds have been given from the time of Halley. Let me offer as a simple question in the mathematical physics of the atmosphere whether a variation of two points in the direction of the south-east Trade Wind between the years 1903 and 1905 can be regarded as real, and, if not, which of the two recorded directions is the correct one?

It would be appropriate for me to add some words about the results of last year's work upon the upper air, in which we have had the valuable co-operation of the University of Manchester. These results have disclosed a number of points of unusual interest. But we are to have an opportunity of considering that subject in a discussion before the Section, and I need not deal with it here. I must, however, pause to give expression of the thanks of all meteorologists to Professor Schuster for his support of the Manchester University station at Glossop Moor. I may remind you that this generous contribution for the advancement of science on the part of Professor Schuster is in addition to the foundation of a readership in mathematical physics at Manchester and a readership in dynamical meteorology, now held by Mr. Gold at Cambridge.

I have said enough to show that the speculative ventures of official meteorologists are not all failures, and I will only add that if any mathematician or physicist would like to take his luck on a meteorological argosy he will be heartily welcomed. Part of the work will be drudgery; he must be prepared to face that; but the prospects of reaching port are reasonably good, so much so, indeed, that such a voyage might fairly lead to a claim for one of the higher academical degrees.

Up to now I have been dealing with the adjustment of official scientific work to reduce waste to a minimum, in so far as it lies within the control of those responsible for an office. I turn now to an aspect of the matter in which we require the assistance of others, particularly of the British Association.

The most serious danger of waste in a busy office is that it should carry on its

[1] This statement is a modification of that contained in the Address as originally printed. The original was based upon a diagram reproduced in the Report of the Meteorological Committee, 1908, in which the phase of the southerly semi-diurnal component is unfortunately incorrect.

work without an adequate knowledge of what is being done in advancing science and improving methods elsewhere. I speak myself for the Meteorological Office alone, but I believe that the responsible officials of any scientific Government department will agree with what I say.

Year by year some Timotheus 'with his sounding flute and tuneful lyre' performs some miracle by the application of reasoning to the phenomena of Nature. Only last year you heard Professor Love in his Presidential address treat of the mundane question of the shape of the earth and etherealise the grim actualities with the magic of his spherical harmonics. Year by year, in every one of the subjects in which the practical world is immediately interested, active students, whether public officials, academic officials, or private enthusiasts, not only keep alight the sacred flame but occasionally add to its brilliance; and all the new knowledge, from whence soever it comes, ought to be applied to the service of the State.

The actual volume of original contributions on these subjects is by no means inconsiderable. You are all aware that, some years ago, the Royal Society initiated a great international enterprise for the compilation of a catalogue of scientific literature. I have been looking at the fifth annual issue of the volume on Meteorology, including Terrestrial Magnetism. I may remark that the catalogue is quite incomprehensibly eclectic as regards official literature, but let that pass. I find that, in the year that closed with July 1907, 1,042 authors (not counting offices and institutions as such) presented to the world 2,131 papers on Meteorology, 229 on Atmospheric Electricity, and 180 on Terrestrial Magnetism. This will give some idea of the annual growth in these subjects, and may convince you that, after all allowance is made for duplicate titles, for papers of no importance, and for mere sheets of figures published for purposes of reference, there remains a bulk of literature too large for any single individual to cope with if he has anything else to do.

If instead of confining ourselves to what can be included in meteorology alone we extend our view over the other allied sciences, it would be necessary to take in other volumes of the international catalogue, and there would be some overlapping. I have taken instead the volume of the 'Fortschritte der Physik' for 1906, which deals with 'Kosmische Physik.' It is edited by Professor Assmann, who adds to his distinction as head of the Royal Prussian Aeronautical Observatory of Lindenberg that of an accomplished bibliographer. In this volume are given abstracts or titles of the papers published during the year which can be regarded as worthy of the attention of a physicist. An examination of the volume gives the following numbers of the papers in the different sections:—

		Papers
Astro-Physics		222
Meteorology		1,122
Atmospheric Electricity		135
Geophysics:		
Geodetics	105	
Seismology and Volcanic Phenomena	256	
Terrestrial Magnetism and Aurora	108	
Currents, Tides, and Waves	46	
Inland Hydrography	117	
Ice, Glaciers, and Ice Age	139	
Other papers	126	
		897
Total		2,376

I need hardly say that these 2,376 papers are not all English; in some of the sections few of them are in that language, and fewer still are British. If British students, official and unofficial, are to make the most of the operation of drawing the angels down, they need help and co-operation in dealing with this mass of literature, in winnowing the important from the unimportant, and in assimilating that which makes for the real progress of the practical application of Science.

This is the more necessary for these subjects because there is no organised system of academic teaching, with its attendant system of text-books. In a subject which has many university teachers it might reasonably be supposed that any important contribution would find its way into the text-books, which are constantly revised for the use of students; and yet, in his Presidential address to the Royal Society in the November of last year, Lord Rayleigh felt constrained to point out that, for the advance of science, although the main requirement is original work of a high standard, that alone is not sufficient. 'The advances made must be secured, and this can hardly be unless they are appreciated by the scientific public.' He adds that 'the history of science shows that important original work is liable to be overlooked and is, perhaps, the more liable the higher the degree of originality. The names of T. Young, Mayer, Carnot, Waterston, and B. Stewart will suggest themselves to the physicist, and in other branches, doubtless, similar lists might be made of workers whose labours remained neglected for a shorter or longer time.'

If this is true of physics how deplorably true it is of meteorology. If I allow a liberal discount of over 50 per cent. from the numbers that I have given, and estimate the number of effective contributions to meteorology as recognised by the 'International Catalogue' at a thousand, which agrees pretty well with that given by the 'Fortschritte der Physik,' and if I were to ask round this room the number of these papers read by anyone here present, I am afraid the result would be disheartening. Many of us have views as to the way in which the study of meteorology ought to be pursued, but the views are not always based on an exhaustive examination of the writings of meteorologists. Few of us could give, I think, any reasonable idea of the way in which it is being pursued by the various institutions devoted to its application, and of the progress which is being secured therein. Meteorological papers are written by the hundred, and, whether they are important or unimportant, they often disregard what has been already written in the same or some other language, and are themselves in turn disregarded. I do not think I should be doing any injustice if I applied similar remarks to some of the other subjects included in the table which I have quoted. How many readers are there in this country for an author in terrestrial magnetism, atmospheric electricity, limnology, or physical oceanography? But, if the papers are not read and assimilated, the advancement of science is not achieved, however original the researches may be.

By way of remedy for the neglect of important papers in physics Lord Rayleigh suggests that teachers of authority, who, from advancing years or from some other reason, find themselves unable to do much more work in the direction of making original contributions, should make a point of helping to spread the knowledge of the work done by others. But what of those subjects in which there are no recognised teachers?—and in this country this is practically the case with the subjects which I have mentioned. It is true that many of them are made the occasion of international assemblies, at which delegates or representatives meet. But such international assemblies are of necessity devoted, for the most part, to the elaboration of the details of international organisation, and not to the discussion of scientific achievements. The numbers attending are, equally of necessity, very restricted.

The want of opportunity for the discussion of progress in these sciences is specially lamentable, because in its absence they lose the valuable assistance of amateur workers, who might be an effective substitute for the students of an academic study. In no subject are there more volunteers, who take an active part in observing, than in meteorology; but how few of them carry their work beyond the stage of recording observations and taking means. The reason is not lightly to be assigned to their want of capacity to carry on an investigation, but far more, I believe, to the want of knowledge of the objects of investigation and of the means of pursuing them.

Among the agencies which in the past have fostered the knowledge of these subjects, and stimulated its pursuit, there stand out prominently the Annual Meetings of this Association. It was the British Association which in 1842 re-founded the Kew Observatory for the study of the physics of the atmosphere, the earth, and the sun. It was the British Association which promoted the establishment of magnetic observatories in many parts of the earth, and in the early sixties secured the most brilliant achievements in the investigation of the atmosphere by means of balloons. I know of no other opportunity of anything like the same potentialities for the writers of papers to meet with the readers, and to confer together about the progress of the sciences in which they are interested. But its potentialities are not realised. Those of us who are most anxious for the spread of the application of mathematics and physics to the phenomena of astronomy, meteorology, and geophysics have thought that this opportunity could not properly be utilised by crowding together all the papers that deal with such subjects into one day, or possibly two days, so that they can be polished off with the rapidity of an oriental execution. In fact, the opportunity to be polished off is precisely not the opportunity that is wanted. There are some of us who think that a British Association week is not too long for the consideration of the subjects of which a year's abstracts occupy a volume of six hundred pages, and that, if we could extend the opportunity for the consideration of these questions from one or two days to a week, and let those members who are interested form a separate committee to develop and extend these subjects, the British Association, the country, and science would all gain thereby. I venture from this place, in the name of the advancement of science, to make an appeal for the favourable consideration of this suggestion. It is not based upon the depreciation, but upon the highest appreciation of the service which mathematics and physics have rendered, and can still render, to the observational sciences, and upon the well-tried principle that close family ties are strengthened, and not weakened, by making allowance for natural development.

The plea seems to me so natural, and the alternatives so detrimental to the advancement of science in this country, that I cannot believe the Association will turn to it a deaf ear.

The following Papers and Reports were then read:—

1. *Discussion on the Isothermal Layer of the Atmosphere, opened by* Dr. W. N Shaw, *F.R.S.*

Dr. Shaw, in the absence of M. L. Teisserenc de Bort, opened the discussion. He explained what was the main feature of the phenomenon, and showed how it had been corroborated by *ballons-sondes* ascents made in England. The temperature of the air decreases in the lower layers on the average at 5° or 6° C. per kilometre up to a height of about ten kilometres. Above this height the temperature ceases to fall rapidly, and falls very slowly indeed, or remains constant, or in some cases increases. It had been suggested that the phenomenon might be due to a change in the composition of the air at great heights.

M. L. Teisserenc de Bort had succeeded in sending up balloons carrying vacuum tubes, which were opened and re-sealed electrically at a height of fourteen kilometres. The samples of air so obtained were examined spectroscopically, and the examination showed that there was no change in the composition of the air sufficient to account for the cessation of temperature diminution.

It was intended that M. L. Teisserenc de Bort should open the discussion; but he was unable to be present and sent the following communication:—

'Permit me to open the discussion on the Isothermal Layer, and the inversions of temperature which are found there, by recalling in a few words the results obtained during the past twelve years. Our experiments at Trappes have shown in the first place that the temperature ceased to diminish at a certain height after having passed through a point of maximum rate of decrease about 3,000 metres lower down.

'The altitude at which the diminution ceases changes with the character of the weather: it may descend as low as eight kilometres at Paris during a cyclone, while it rises as high as thirteen or fourteen kilometres in high-pressure areas and in front of large cyclones.

'I indicated these peculiarities for the first time in October 1901, in a communication to the Luftschiffart-Verein at Berlin, then in a communication to the Meteorological Society of France in March 1902, and I have developed these conclusions in a note to the Académie des Sciences in April 1902.

'A short time after, in the early part of May 1902, Prof. Assmann showed from ascents of six rubber balloons that not only was there a cessation of the decrease of temperature but also an inversion. This inversion had also been very marked in the first ascents by Hermite and Besançon, but Prof. Assmann sought to explain it as being due to the effect of solar radiation on the thermometer, while the ventilation produced by the rapid ascent of the balloon showed that it could not be referred to such an error in the thermometer record.

'Having once demonstrated the existence of this isothermal layer for places in the neighbourhood of Paris, we sought to find the evidence of it in other regions, in order to show that it was a general phenomenon. Ascents made by us and our assistants in the winter of 1900-1901, by M. de Quervain in Russia, by Mr. Eggenberger at Bath in England in 1902, have made it evident that the phenomenon was a general one. On referring to the results of the international ascents made in different countries, it is seen that the cessation of the temperature decrease is found in the case of all the balloons sent up, and that it is impossible to refer it to insufficient ventilation, since the phenomenon was well marked in ascents made during the night. Since this time ascents made on board the "Princess Alice" by Prof. Hergesell in 1905 have furnished evidence of the existence of the layer near the Azores; ascents made in the United States by Mr. A. L. Rotch have furnished evidence of its existence there, with the peculiarities I have indicated, *i.e.*, high up over high-pressure areas and low down over low-pressure areas.

'The expeditions of the "Otaria," organised in conjunction with my friend Mr. Rotch, have proved the existence of the zone in the tropics, and have shown that it is further from the earth near the equatorial regions, where the Trade Winds meet.

'Finally, the ascents made at the end of the winters of 1907 and 1908 by the French-Swedish expedition organised by the Observatory of Trappes, with the support of Prof. Hildebrandson, have shown that near the Arctic Circle at Kiruna the layer exists and possesses general characteristics analogous with those found in these regions.

'The results of series of daily ascents for eight, ten, or more days in succession in February 1901, March 1903, and May 1904 have proved that the change of altitude of the point where the temperature ceases to fall is accompanied by changes of temperature of 10°, 15°, 20° C., in an interval of a day or two at heights between nine and thirteen kilometres, variations great enough to be felt near the surface during the same time.

'Thus the equalisation of temperature in the course of the year which had been supposed to be nearly complete at eight or nine kilometres' altitude does not exist, but, on the contrary, sudden changes of temperature occur with the passage of cyclones and anticyclones, which would furnish to an observer in those regions the chief evidence of the changes occurring at the surface.

'*Causes of the Isothermal Layer.*—The summary of the observed phenomena has led me to this conclusion: that the cessation of the temperature diminution is due to the fact that there is at these heights no considerable vertical convection.

'The fact that one meets with layers of air thousands of metres thick where the temperature increases and decreases rapidly, and others where it is stationary, is incompatible with the existence of motion of the air accompanied by pressure variations, which always tend to produce a vertical temperature gradient more or less near that for the adiabatic state. It does not follow that the movement in the isothermal layer must be horizontal, but that it takes place along the isobars without crossing these surfaces nearly in the manner in which a body rolls on an inclined plane.

'These ideas have been developed in several communications, in particular at the Conférence d'Aérostation scientifique at St. Petersburg in September 1904

(i) *Theodolite Observations of Balloons penetrating the Isothermal Layer.* *By* C. J. P. Cave.

At the end of July, on the days arranged for balloon ascents by the Commission for Scientific Aeronautics, theodolite observations were made at Ditcham Park on four *ballons-sondes* carrying instruments, and on one large balloon of the same kind, but carrying no instrument. The balloons used were supplied by M. Paturel of Paris, and were nominally 1·75 metre in diameter; their weight was about 0·2 kg., and they were filled with hydrogen to lift 0·8 kg. in addition to their own weight; the instrument, label, and string weighed from 75 to 80 grammes; there was also a balloon nominally of 1 metre in diameter and weighing 80 grammes, filled to lift 30 grammes in addition to its own weight; it trailed below the instruments during the ascent, and was intended to serve as a check to the descent and as an aid to the finding of the instruments.[1] The large balloons were uncoloured, and were very plainly visible by reflected sunlight against the clear sky. The ascents began about an hour before sunset.

Observations were made by means of two theodolites placed about 2·68 km. apart; owing to the distance to which the balloons went, and sometimes to their direction with regard to the base-line, it was not possible to plot the more distant part of the trajectories from the two sets of observations; accordingly the rate of ascent was determined up to the point at which the two-theodolite method ceased to be reliable, and was subsequently assumed to be uniform, and the positions of the balloon were plotted from the observations of one theodolite. It is probable that the balloons did not ascend with uniform velocity; the velocity probably increases as the balloon ascends. The assumption of a uniform velocity, however, probably gives a fair approximation of the trajectories of the balloons. From the plotted trajectories the wind velocities are determined for each minute interval, and are finally plotted to show the relation of wind velocity to height.

The first balloon of the series was sent up on July 27, but was lost to sight at a height of about 8·5 km. The balloon of July 28 was kept in sight to a height of 13 km.; the wind velocity increased from about 5 miles an hour at 2 km. to 50 miles per hour at 8 km.; above this it remained fairly constant to 11 km., when there was some increase, a maximum between 50 and 60 miles per hour being indicated at 11·5 km.; above this the velocity decreased rapidly, being about 8 miles per hour at 13 km.; the wind, which had been from the north or a little west of north, was more from the west at the greatest heights. The record from the meteorograph carried by this balloon shows that the isothermal layer was entered at 11·5 km. The wind velocities for July 29 are very similar to those for the previous day, the maximum of from 50 to 60 miles per hour being reached at 11·5 km.; the subsequent decrease, however, was not so rapid, the velocity being still 20 miles per hour at 13·2 km. The balloon of July 30 shows smaller wind velocities above 7 km. than on the three previous days, the wind being fairly steady at from 25 to 30 miles per hour; there was some increase at 10·5 km. to 35 miles per hour, followed by a slow but steady decrease to 25 miles per hour at 11·7, when the balloon was lost to sight. Unfortunately the balloons of this and the previous day went out to sea and the meteorographs were not recovered. On July 31 a 1·75-metre balloon, filled to the same amount as the balloons of the previous days, was sent up without instruments: this showed very large wind velocities, increasing from 10 miles per hour at ground level to 80 miles per hour at 11·5 km.; above this there was a decrease to about 55 miles per hour at 13·5 km., when the balloon was seen to burst.

In all cases, therefore, in which the balloon was watched to heights of above 11 kilometres the wind velocity reached a maximum value at a little above this height, followed by a decrease above.

[1] Owing to the small balloon the instrument of July 28 was recovered; it fell in the Channel, and the balloon kept it afloat for three days.

(ii) *The Warm Stratum in the Atmosphere at Heights exceeding Eight Miles in the United States. By* Professor A. LAWRENCE ROTCH.

The only *ballons-sondes* that have been used in America are those launched by the author. Since his observatory at Blue Hill lies too near the coast for the purpose, most of the balloons have been despatched from St. Louis, Missouri. The experiments were begun in September 1904, and have been continued since that time, during different seasons, with the aid of grants from the Smithsonian Institution. Of the seventy-six balloons sent up from St. Louis, all but four have been found and returned, the majority falling within a radius of two hundred or three hundred miles to the eastward of St. Louis. The balloons are of rubber, the instruments of Teisserenc de Bort's construction, calibrated for low pressures and temperatures before each ascension, and all ascensions were made after sunset, to avoid the effect of solar radiation.

Most of the balloons which rose higher than eight miles (12,870 metres) entered the warm stratum, whose temperature continued to increase with increasing height. The stratum was at its lowest level in summer, with a mean minimum temperature of $-54°\cdot6$ C. at 12,000 metres. During the autumn of 1907 the warm stratum was penetrated eight times, the mean minimum temperature of $-60°\cdot5$ C. occurring at 12,370 metres. The variations in height from day to day were large, a minimum temperature of $-67°\cdot1$ C. at a height of 14,500 metres on October 8 being followed, two days later, by a descent of the minimum temperature of $-62°\cdot2$ C. to 12,000 metres. The temperatures at the extreme heights reached were $-58°$ C. at 16,500 metres on October 8 and $-56°$ C. at 15,000 metres on October 10, showing an increase of 9° C. in 2,000 metres and $-6°\cdot2$ in 4,500 metres respectively. On November 6 the minimum temperature of $-52°\cdot2$ C. was found at 9,700 metres, and $-50°\cdot5$ C. at 10,000 metres, the highest point attained. On November 8 the level of the minimum of $-63°\cdot1$ C. had risen to 14,250 metres, with an increase of temperature to $-60°\cdot2$ C. at 15,380 metres. These observations are to be published *in extenso* and discussed in the 'Annals of the Astronomical Observatory of Harvard College,' under the author's direction.

These results, which were made near 35° North latitude, show the warm stratum to be at a decidedly higher altitude than it is in northern Europe. On the contrary, the results obtained by the expedition which was sent jointly by M. Teisserenc de Bort and the author in 1906–7 to explore the atmosphere over the tropical Atlantic indicated a still higher level for the warm stratum. In fact at the height of 15,000 metres over the equator there was no inversion of temperature, and it was actually colder than at an equal height in the northern latitudes.

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2. *Report on the Measurement of the Geodetic Arc in Africa.* See Reports, p. 56.

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3. *Seventh Report on the Investigation of the Upper Atmosphere by means of Kites.*—See Reports, p. 59.

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4. *Report on the Magnetic Observations at Falmouth Observatory.* See Reports, p. 55.

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5. *Report of the Committee on Electrical Standards.*—See Reports, p. 31.

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6. *Report on Meteorological Observations on Ben Nevis.*—See Reports, p. 58.

FRIDAY, SEPTEMBER 4.

Joint Discussion with Sections B and G on Gaseous Explosions.

DEPARTMENT OF MATHEMATICS.

The following Report and Papers were read :—

1. *Report on Bessel Functions.*—See Reports, p. 58.

2. *The Asymptotic Expansions of Bessel Functions.* *By* J. W. NICHOLSON, *D.Sc., B.A.*

The tabulation of Bessel functions, so far as it has yet been carried out, has been chiefly based upon the formulæ

$$J\ (z)=\sqrt{\frac{2R}{\pi z}}\cos\left(z+a-\frac{n\pi}{2}-\frac{\pi}{4}\right)$$

$$R=P^2+Q^2,\quad a=\sin^{-1}\frac{Q}{R}$$

$$P=1-\frac{4n^2-1^2\ .\ 4n^2-3^2}{2\ !\ (8z)^2}+\ .\ .\ .$$

$$Q=\frac{4n^2-1^2}{8z}-\frac{4n^2-1^2\ .\ 4n^2-3^2\ .\ 4n^2-5^2}{3\ !\ (8z)^3}+\ .\ .\ .$$

as, for example, in the case of a tabulation now being made by a Committee of the Association.[1]

These formulæ are only useful when z is fairly large and n small in comparison. Suitable bases of calculation for larger values of n have recently been obtained by the author. There are three distinct cases for the Bessel functions of real argument.

Case 1 : n less than z.

Writing
$$J_n(z)=\sqrt{\frac{2R}{\pi z}}\sin\rho$$

$$J_{-n}(z)-\cos n\pi\ J_n(z)=\sin n\pi\sqrt{\frac{2R}{\pi z}}\cos\rho\ (n\text{ not an integer})$$

$$Y_n(z)=-\sqrt{\frac{2\pi R}{z}}\cos\rho\ (n\text{ an integer})$$

where $Y_n(z)$ is the solution defined by

$$Y_n(z)=\left\{\frac{\partial J_n(z)}{\partial n}-(-)^n\frac{\partial J_{-n}(z)}{\partial n}\right\}(n=\text{integer})$$

Then if $n=z\sin a$, and a is not too close to 90°

$$R=\sec a+\frac{\lambda_2}{z^2}\sec^3 a+\frac{\lambda_4}{z^4}\sec^4 a+\ .\ .\ .$$

where $4\ (s+3)\ \lambda_{s+3}+(s+2)^3\ \lambda_{s+1}+2n^2s\ .\ s+1\ .\ s+2\ .\ \lambda_{s-1}+n^4s\ ,\ s^2-4\ .\ \lambda_{s-3}=0$

$$\lambda_2=-\frac{1}{2^3},\ \lambda_4=\frac{27-96n^2}{2^7},\ \lambda_6=\frac{4640n^2-1125-640n^4}{2^{10}}$$

and the second, fifth, eighth, &c., terms of R are two orders in n or z less than those preceding.

[1] *B.A. Report*, 1907, p. 94.

If also $$1+\mu_2 x^2+\mu_4 x^4+\ \ldots=(1+\lambda_2 x^2+\lambda_4 x^4+\ldots)^{-1}$$

then $$\rho=\frac{\pi}{4}+z\,(\cos a-\overline{\frac{\pi}{2}-a}\,\sin a)-\frac{a}{n}\,(\mu_2-\frac{\mu_4}{n^2}+\frac{\mu_6}{n^4}-\ \ldots)$$

$$-\frac{\mu_4}{n^3}\tan a+\frac{\mu_6}{n^5}\,(\tan a-\frac{1}{3}\tan^3 a)-\frac{\mu_8}{n^7}\,(\tan a-\frac{1}{3}\tan^3 a+\frac{1}{5}\tan^5 a)\ \ldots$$

where the orders decrease similarly.

Case 2: n greater than z.

If $n=z\cosh\beta$, β not being small,

$$J_n(z)=\sqrt{\frac{2\tau}{\pi z}}\,e^t$$

$$J_{-n}(z)-\cos n\pi\,J_n(z)=\sin n\pi\sqrt{\frac{2\tau}{\pi z}}\,e^{-t}\qquad (n \text{ not integral})$$

$$Y_n(z)=-\sqrt{\frac{2\pi\tau}{z}}\,e^{-t}\qquad (n \text{ integral})$$

Then $$2\tau\sinh\beta=1-\frac{\lambda_2}{n^2}\coth^2\beta+\frac{\lambda_4}{n^4}\coth^4\beta\ \ldots$$

$$t=n\,(\tanh\beta-\beta)-\frac{1}{2}\log_e 2-\frac{1}{n^3}\,(\mu_4-\frac{1}{3}\frac{\mu_6}{n^2}+\frac{1}{5}\frac{\mu_8}{n^4}\ \ldots)$$

$$+\frac{1}{n^3}\,(\mu_4\coth\beta-\frac{\mu_6}{3n^2}\coth^3\beta+\ldots)+\frac{B_1}{n}\frac{1!}{2!}-\frac{B_2}{n^3}\frac{2!}{4!}+\frac{B_3}{n^5}\frac{4!}{6!}\ \ldots$$

where the B's are the Bernoullian numbers, and orders decrease as before.

Case 3: when n and z are nearly equal, and fairly large, $J_n(z)$ may be reduced to an Airy's integral [1] in the form

$$J_n(z)=\frac{1}{\pi}\left(\frac{6}{z}\right)^{\frac{1}{3}}\int_0^\infty \cos\left\{w^3+\overline{n-z}\left(\frac{6}{z}\right)^{\frac{1}{3}}w\right\}dw$$

and its tabulation may be conducted at once by the use of tables given for this integral by Airy and later by Stokes.[2]

In particular

$$J_n(n)=\Gamma\left(\frac{1}{3}\right)2^{-\frac{2}{3}}\,3^{-\frac{1}{6}}\,\pi^{-1}\,n^{-\frac{1}{3}}$$

This is correct to three places of decimals when $n=8$, and to four when $n=10$ so that it is not necessary for n to be very large.

Similarly

$$J_{-n}(n)=\Gamma\left(\frac{1}{3}\right).\,2^{\frac{1}{3}}\,3^{-\frac{1}{6}}\,\pi^{-1}\,n^{-\frac{1}{3}}\cos\left(n\pi-\frac{\pi}{3}\right)$$

$$Y_n(n)=-\Gamma\left(\frac{1}{3}\right)2^{-\frac{2}{3}}\,3^{\frac{1}{3}}\,n^{-\frac{1}{3}}$$

More generally, if

$$F(\rho)=\int_0^\infty\cos\,(w^3+\rho w)\,dw$$

$$f(\rho)=\int_0^\infty\sin\,(w^3+\rho w)\,dw$$

$$\rho=\overline{n-z}\,.\left(\frac{6}{z}\right)^{\frac{1}{3}}$$

[1] Airy, *Camb. Phil. Trans.*, vi. p. 379; viii. p. 595.

[2] *Math. and Phys. Papers*, ii. p. 329 *et seq.*

then

$$J_n(z) = \frac{1}{\pi}\left(\frac{6}{z}\right)^{\frac{1}{3}} F(\rho)$$

$$J_{-n}(z) = \frac{1}{\pi}\left(\frac{6}{z}\right)^{\frac{1}{3}} \{\cos n\pi \,.\, F(\rho) + \sin n\pi \,.\, f(\rho)\}$$

$$+ \frac{\sin n\pi}{\pi}\left(\frac{6}{z}\right)^{\frac{1}{3}} e^{\iota\pi/6} \{F(\rho e^{-\iota\pi/3}) + \iota f(\rho e^{-\iota\pi/3})\}$$

$$Y_n(z) = -\left(\frac{6}{z}\right)^{\frac{1}{3}} \{e^{\iota\pi/3} F(\rho e^{-\iota\pi/3}) + e^{-\iota\pi/3} f(\rho e^{-\iota\pi/3})\}$$

when n and z are nearly equal. These lead to the series, when ρ is small,

$$J_n(z) = \frac{1}{3\pi}\left(\frac{6}{z}\right)\left\{\Gamma\left(\frac{1}{3}\right)\cos\frac{\pi}{6} + \frac{\rho}{1\,!}\Gamma\left(\frac{2}{3}\right)\cos\frac{5\pi}{6} + \frac{\rho^2}{2\,!}\Gamma\left(\frac{3}{3}\right)\cos\frac{9\pi}{6} + \ldots\right\}$$

$$J_n(z) = \frac{2}{3\pi}\left(\frac{6}{z}\right)^{\frac{1}{3}}\left\{\Gamma\left(\frac{1}{3}\right)\sin\frac{\pi}{3}\cos\left(n\pi - \frac{\pi}{3}\right) + \frac{\rho^2}{1\,!}\Gamma\left(\frac{2}{3}\right)\sin\frac{2\pi}{3}\cos\left(n\pi - \frac{2\pi}{3}\right) + \ldots\right\}$$

$$Y_n(z) = -\frac{1}{3}\left(\frac{6}{z}\right)^{\frac{1}{3}}\left\{\Gamma\left(\frac{1}{3}\right)\left(1 + \sin\frac{\pi}{6}\right) + \frac{\rho}{1\,!}\Gamma\left(\frac{2}{3}\right)\left(1 + \sin\frac{5\pi}{6}\right) + \ldots\right\}$$

The Bessel functions, whose argument is purely imaginary, are usually defined by

$$I_n(z) = \iota^{-n} J_n(\iota z)$$

$$K_n(z) = \frac{\sqrt{\pi}}{\Gamma(n+\frac{1}{2})}\left(\frac{z}{2}\right)^n \int_0^\infty e^{-z\cosh\phi} \sinh^{2n}\phi \, d\phi$$

the latter being zero at infinity.

These have the expansions when either n or z is large.

$$I_n(z) = \sqrt{\frac{\tau}{2\pi z}}\, e^t$$

$$K_n(z) = \sqrt{\frac{\pi\tau}{2z}}\, e^{-t}$$

where if $n = z \sinh \beta$

$$\tau = \operatorname{sech}\beta - \lambda_2 \operatorname{sech}^3\beta + \lambda_4 \operatorname{sech}^4\beta \ldots$$

$$t = z\left(1 - \frac{\mu_2}{z^2} D - \frac{\mu_4}{z^4} D^{-2} \ldots\right)\{\cosh\beta - \beta\sinh\beta\}$$

where $$D = \frac{1}{\sinh\beta\cosh\beta} \cdot \frac{\partial}{\partial\beta}$$

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3. *On Sir W. R. Hamilton's Fluctuating Functions.* *By* E. W. Hobson, *Sc.D., F.R.S.*

This paper dealt with the mode of representation of an arbitrary function by means of definite integrals involving the fluctuating functions just introduced by Hamilton in his memoir 'On Fluctuating Functions,' published in the 'Transactions of the Royal Irish Academy' in the year 1843. The results obtained by Hamilton were discussed in a rigorous manner, and were extended to the case in which the function to be represented is of the very general type limited only by the postulation that the function possesses a Lebesque integral in the interval for which it is to be represented. General theorems are obtained containing sufficient conditions for the convergence of the integrals at points in the limited or unlimited interval of representation, and also sufficient conditions for the uniform representation of the function in any portion of the interval in which that function is continuous. It was shown that the subsidiary functions employed by Hamilton are a particular case of a more general class of functions, the properties of which have been recently discussed by the author in the 'Proceedings of the London Mathematical Society,' vol. vi.

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4. *On the Law of Equipartition of Energy between Correlated Variables.* *By* S. H. Burbury, *F.R.S.*

I think the law has never yet been proved except on the assumption, express or implied, that the variables are *not* correlated.

Let, then, $x_1 \ldots x_n$ be n quantities which vary continuously between limits given by $\Sigma mx^2 = E$, a constant, and which are, or some of them are, correlated *inter se.* Let the chance that, subject to constants, they shall respectively lie between x_1 and $x_1 + dx_1$, x_2 and $x_1 + dx_2$, &c., be denoted by $\phi(x_1 \ldots x_n)dx_1 \ldots dx_n$. Then their mean values, $\overline{x_1}$, $\overline{x_2}$, &c., are

$$\overline{x_1} = \iint \ldots \phi(x_1 \ldots x_n)x_1 dx_1 \ldots dx_n$$

$$\overline{x_2} = \iint \ldots \phi(x_1 \ldots x_n)x_2 dx_1 \ldots dx_n, \text{ \&c.}$$

Also their mean squares are

$$\overline{x_1^2} = \iint \ldots \phi(x_1 \ldots x_n)x_1^2 dx_1 \ldots dx_n, \text{ \&c.}$$

And by virtue of the correlation any two of them, as x_p and x_q, have a mean product

$$\overline{x_p x_q} = \iint \ldots \phi(x_1 \ldots x_n)x_p x_q dx_1 \ldots dx_n.$$

For my present purpose I must assume that every $\overline{x} = 0$. Also let $\overline{x_1^2} = a_1$, $\overline{x_2^2} = a_2$, &c., and $\overline{x_1 x_2} = b_{12} = b_{21} \ldots \overline{x_p x_q} = b_{pq} = b_{qp}$, &c.

Introduce now n new variables $u_1 \ldots u_n$, such that

$$\left.\begin{aligned} x_1 &= a_1 u_1 + b_{12}u_2 + b_{13}u_3 + \ldots + b_{1n}u_n \\ x_2 &= b_{21}u_1 + a_2 u_2 + \ldots \\ x_n &= b_{n1}u_1 + b_{n2}u_2 + \ldots + a_n u_n \end{aligned}\right\} \quad \ldots \quad (1)$$

And by consequence

$$u_1 = x_1 \frac{D_{11}}{D} + x_2 \frac{D_{12}}{D} + x_3 \frac{D_{13}}{D} + \ldots + x_n \frac{D_{1n}}{D} \quad \ldots \quad (2)$$

with corresponding values for $u_2 \ldots u_n$.

Here D is the determinant of the coefficients a, b as they stand in (1), and D_{pq} is its minor, omitting row p and column q, or *vice versa.*

The *law of probability* is then

$$\phi(x_1 \ldots x_n) = e^{-\frac{1}{2}(x_1 u_1 + x_2 u_2 + \ldots + x_n u_n)}$$

ultiplied by a constant.

In the first equation of (1) multiply each side by x_1. That gives

$$x_1 u_1 = x_1^2 \frac{D_{11}}{D} + x_1 x_2 \frac{D_{12}}{D} + x_1 x_3 \frac{D_{13}}{D} + \text{\&c.} \quad \ldots \quad (3)$$

Now the values of the coefficients a, b, and therefore of D and its minors, do not change between one set of values of $x_1 \ldots x_n$ and another, but are the same for all values of $x_1 \,.\,.\, x_n$ and the consequent values of $u_1 \,.\,.\, u_n$. Therefore we may multiply both sides of (3) by $\phi(x_1 \,.\,.\, x_n)$ and integrate for all values of $x_1 \,.\,.\, x_n$, regarding a, b as constants. And since

$$\iint \,.\,.\, \phi(x_1 \,.\,.\, x_n) x_1 u_1 dx_1 \,.\,.\, dx_n = \overline{x_1 u_1}$$

we obtain

$$\overline{x_1 u_1} = \iint \,.\,.\, \phi(x_1 \,.\,.\, x_n) dx_1 \,.\,.\, dx_n \left\{ x_1^2 \frac{D_{11}}{D} + x_1 x_2 \frac{D_{12}}{D} + \&c. \right\}$$

$$= \frac{a_1 D_{11} + b_{12} D_{12} + b_{13} D_{13} + \&c.}{D}$$

$$= \frac{D}{D} = 1.$$

Similarly

$$\overline{x_2 u_2} = 1, \&c. \quad \text{And } \overline{x_1 u_1} = \overline{x_2 u_2} = \&c.$$

Or if

$$Q = \tfrac{1}{2}\Sigma xu, \; \overline{x_1 \frac{dQ}{dx_1}} = \overline{x_2 \frac{dQ}{dx_2}} = \&c.$$

This is the law of equipartition of Q.

I now introduce the following principle:—

Making Q minimum, *i.e.*, e^{-Q} maximum, subject to the kinetic energy E being constant, we find the most probable, or *normal*, state of the system. That is, since Q is minimum

$$\Sigma \frac{dQ}{dx} \partial x = 0$$

and since E is constant

$$\Sigma \frac{dE}{dx} \partial x = 0$$

whence by the usual method

$$\frac{dQ}{dx_1} = \lambda \frac{dE}{dx_1}, \quad \frac{dQ}{dx_2} = \lambda \frac{dE}{dx_2}, \; \&c.$$

The indeterminate multiplier λ is a function of the a's and b's. Therefore we may write

$$x_1 \frac{dQ}{dx_1} = \lambda x_1 \frac{dE}{dx_1}, \quad x_2 \frac{dQ}{dx_2} = \lambda x_2 \frac{dE}{dx_2}.$$

And this being true for all values of $x_1 \,.\,.\, x_n$ consistent with E = constant

$$\overline{x_1 \frac{dE}{dx_1}} \Big/ \overline{x_2 \frac{dE}{dx_2}} = \overline{x_1 \frac{dQ}{dx_1}} \Big/ \overline{x_2 \frac{dQ}{dx_2}} = 1.$$

That

$$\overline{x_1 \frac{dE}{dx_1}} = \overline{x_2 \frac{dE}{dx_2}}.$$

And if $E = \Sigma m x^2$, $\overline{m_1 x_1^2} = \overline{m_2 x_2^2}$, &c.

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5. *The Complementary Theorem.* *By* Professor J. C. Fields.

Let $F(z, v) = 0$ be an integral algebraic equation. Any rational function can be written in the forms

$$(1) \qquad H(z, v) = P(z, v) + \sum_k \frac{\phi^{(i_k)}(z, v)}{(z - a_k)^{i_k}} = -\frac{\phi^{(i_k + j)}(\xi, \eta)}{\xi^{i_k}} + \xi^j ((\xi, \eta)),$$

where $\xi = z^{-l}$, $\eta = z^{-m} v$, and z^m is the highest power of z which appears in the equation. If the function is to become infinite to orders not higher than

$$\sigma_1^{(k)},\ \sigma_2^{(k)},\ \ldots\ \sigma^{(k)}_{r_k}$$

respectively for branches of the cycles corresponding to finite values $z = a_k$, and if for $z = \infty$ it is to have orders of coincidence which do not fall short of

$$\tau_1^{(\infty)},\ \tau_2^{(\infty)},\ \ldots\ \tau_{r_\infty}^{(\infty)}$$

respectively, then will the functions ϕ contain certain constants δ, which are arbitrary excepting in so far as they are conditioned by the fact that the two representations are to hold simultaneously for the function. The conditions to which the constants δ are subjected are given by the identity

$$(2)\quad \sum_k \sum_{s=1}^{l} \frac{\delta_s^{(k)} \phi_s^{(i_k)}(z, v)}{(z-a_k)^{i_k}} + \sum_{s=1}^{l_\infty} \frac{\delta_s^{(\infty)} \phi_s^{(i_\infty + j)}(\xi, \eta)}{\xi^{i_\infty}} =$$

$$\text{polynomial in } (z, v) + \xi^j ((\xi, \eta)).$$

This identity can immediately be replaced by another identity.

$$(3)\quad \sum_k \sum_{s=1}^{l_k} \frac{\delta_s^{(k)} \zeta_s^{(i_k)}(z, v)}{(z-a_k)^{i_k}} + \sum_{s=1}^{l_\infty} \frac{\delta_s^{(\infty)} \zeta_s^{(i_k + j)}(\xi, \eta)}{\xi^{i_\infty}} =$$

$$\text{polynomial in } (z, v) + \xi^j ((\xi, \eta))_1,$$

where the several functions[1] ζ have a very simple connection with the corresponding functions ϕ. The conditions to which the constants δ are subjected by this identity are obtained by equating to 0 the coefficients of $z^{-r} v^{n-t}$

$$(0 < r < j + (n-t)\, m,\ t = 1, 2, \ldots, n)$$

on the left-hand side. The equations of condition so obtained are not all independent. A linear equation between them with multipliers $a_{r-1,\, t-1}$ signifies that the coefficient of $z^{-1} v^{n-1}$ in every product

$$(z-a_k)^{-i_k}\ \zeta_s^{(i_k)}(z, v)\ \psi(z, v),$$

and in every product

$$\xi^{-i_\infty}\ \zeta_s^{(i_\infty + j)}(\xi, \eta)\ \psi(z, v)$$

is 0, where

$$\psi(z, v) = \sum a_{r-1,\, t-1}\, z^{r-1}\, v^{t-1}.$$

The interpretation of this is that $\psi(z, v)$ must have orders of coincidence which are complementary adjoint to

$$-\sigma_1^{(k)},\ -\sigma_2^{(k)},\ \ldots\ -\sigma_{r_k}^{(k)}$$

for finite values $z = a_k$, and for the value $z = \infty$ orders of coincidence which are complementary adjoint to

$$\tau_1^{(\infty)} - 2,\ \tau_2^{(\infty)} - 2,\ \ldots,\ \tau_{r_\infty}^{(\infty)} - 2.$$

[1] For details in regard to these functions see the author's book *Theory of the Algebraic Functions of a Complex Variable*, Berlin: Mayer & Müller.

Employing the symbol N_ψ to designate the number of arbitrary constants involved in the most general rational function $\psi(z, v)$ possessing the orders of coincidence here in question, this also represents the number of the equations of condition which are dependent on the remaining ones. We, however, know expressions for the total number of these equations and for the total number of the constants δ. Making use of these expressions we immediately obtain for the number of arbitrary constants δ satisfying the identities (2) and (3)

$$(4) \qquad N_H = N_\psi + n - \tfrac{1}{2} \sum_k \sum_{s=1}^{r_k} (\nu_s^{(k)} - 1) - \sum_k \sum_{s=1}^{r_k} \tau_s^{(k)} \nu_s^{(k)},$$

and this at the same time represents the number of arbitrary constants involved in the most general function $H(z, v)$, whose orders of coincidence for the various values z do not exceed the corresponding numbers $\tau_1^{(k)} \ldots \tau_{r_k}^{(k)}$. Here we have replaced $-\sigma_1^{(k)} \ldots -\sigma_{r_k}^{(k)}$ by the symbols $\tau_1^{(k)} \ldots \tau_{r_k}^{(k)}$. Formula (4) contains one statement of the complementary theorem in a restricted case. From it, however, can immediately be deduced in a variety of forms the theorem in the most general case. This has already been done in the author's book. The principal object of the present paper is to give a method for obtaining formula (4) with greater facility and elegance.

6. *The Genesis of Elliptic Functions.* *By* ROBERT RUSSELL.

DEPARTMENT OF GENERAL PHYSICS.

The following Papers were read:—

1. *Do the Radio-active Gases (Emanations) belong to the Argon Series?* *By* Sir WILLIAM RAMSAY, *K.C.B., F.R.S.*

The residues of the fractionation of 120 tons of liquid air were examined in the chemical laboratory of University College by Professor Moore. After removal of oxygen and nitrogen, argon, krypton, and xenon remained, and were separated by methodical fractionation. The xenon amounted to about 300 cm.^{3}; it was methodically fractionated at $-130°$, and a final residue of 0·3 cm.^{3} was obtained. The spectrum of this portion was photographed, and differed in no respect from that of xenon. It is practically certain that if this residue had contained 1 per cent. of a denser gas, that gas would have been detected. It follows therefore that if there is a heavier constituent in air than xenon, its amount does not exceed 1-25 billionth of the whole. Now it is certain that if such an element existed, it would be gaseous, and would be found in air. Its non-existence implies either the absence of such elements from the periodic table or their instability. As possible atomic weights for missing elements are 178, 216, and 260, it is rendered probable that they are respectively unstable emanations—those of thorium, of radium, and of actinium.

2. *On the Number and Absorption of the β Particles emitted by Radium.* *By* W. MAKOWER.

The experiments were undertaken to redetermine the number of β particles emitted per second by radium C in equilibrium with one gram of radium. Radium emanation was sealed in a small glass tube about 1 mm. diameter, the thickness of whose walls was about 0·1 mm., and the charge reaching a thick insulated brass cylinder surrounding the glass tube per second was measured by a quadrant electrometer. The whole was enclosed in a silvered glass vessel which could be exhausted by means of charcoal and liquid air. In order to allow for the absorption of the β rays from the emanation by the walls of the enclosing glass tube, a series of experiments was made to determine the law of absorption of the β rays from radium B and C when the thickness of glass is varied. It was found that the law of absorption for glass was sensibly the same as for aluminium as found by H. W. Schmidt, the radiation being measured in both cases by the *ionisation* produced by the rays after traversing different thicknesses of glass. It was further found that the law of absorption was the same when measured by the *charge* received by the brass cylinder mentioned above when different thicknesses of glass were interposed between the emanation and the brass cylinder. It is therefore concluded that when rays pass through matter the observed absorption of the rays is not due to *scattering*, but to an *actual stoppage* of the particles by the absorbing medium. The final corrected value for the number of β particles emitted per second from the radium C in equilibrium with 1 gram of radium is $4 \cdot 9 \times 10^{10}$.

3. *The Rate of Production of Helium from Radium.* *By* Sir JAMES DEWAR, *F.R.S.*

DEPARTMENT OF COSMICAL PHYSICS (ASTRONOMY).

The following Report and Papers were read:—

1. *Report of the Seismological Committee.*—See Reports, p. 60.

2. *A Generalised Instrument.* *By* Sir ROBERT BALL, *F.R.S.*

In the altazimuth the telescope should be perpendicular to a horizontal axis II. which is itself carried by a vertical axis I. Owing to instrumental imperfection the angle between the telescope and the axis I. is $90° + r$ and that between I. and II. is $90° - q$ where r and q are small quantities.

In the almucantar the telescope is inclined to the vertical axis II. at the angle $90° + r$, and the vertical axis is inclined to the axis of the Earth I. at the angle $90° - q$, where q is the latitude. In this case r and q are not small quantities.

Thus an investigation in which the circle attached to axis I. has λ for the longitude of its ascending node on the fundamental circle and θ for the angle between axis I. and the normal to the fundamental circle will include the complete theory of the following instruments among others: the Altazimuth, the Meridian Circle, the Prime Vertical Instrument, the Equatorial, and the Almucantar. The instrument so defined we call the *generalised instrument*.

Let a, δ be the co-ordinates of a star and R, R_1 be the readings of Circle I. and Circle II. when the telescope of the generalised instrument is directed on that star, then

$$\left.\begin{aligned} \operatorname{Sin} \delta &= f_1(\lambda, \theta, q, r \,.\, \mathrm{R}\, \mathrm{R}_1) \\ \operatorname{Cos} a \cos \delta &= f_2(\lambda, \theta, q, r \,.\, \mathrm{R}\, \mathrm{R}_1) \\ \operatorname{Sin} a \cos \delta &= f_3(\lambda, \theta, q, r \,.\, \mathrm{R}\, \mathrm{R}_1) \end{aligned}\right\} \quad \ldots\ldots \quad \text{(i)}$$

The following is the most convenient method of writing the formulæ:—

$$\left.\begin{aligned} \operatorname{Sin} \delta &= \mathrm{L} \cos \theta + \mathrm{M} \sin \theta \\ \operatorname{Cos} a \cos \delta &= (\mathrm{L} \sin \theta - \mathrm{M} \cos \theta) \sin \mathrm{L} + \mathrm{N} \cos \lambda \\ \operatorname{Sin} a \cos \delta &= -(\mathrm{L} \sin \theta - \mathrm{M} \cos \theta) \cos \lambda + \mathrm{N} \sin \lambda \end{aligned}\right\} \quad \ldots \quad \text{(ii)}$$

where L, M, N are the direction cosines of the star with respect to their rectangular axes, of which the first is axis I. and the third is the intersection of the circles II. and I., and we have L, M, N expressed in terms of q, r, R, R_1 by these equations:—

$$\left.\begin{aligned} L &= -\sin q \sin r + \cos q \cos r \sin R_1 \\ M \sin R + N \cos R &= \cos r \cos R_1 \\ -M \cos R + N \sin R &= \sin r \cos q + \sin q \cos r \sin R_1 \end{aligned}\right\} \quad . \quad . \quad \text{(iii)}$$

When R and R_1 are observed then from (iii) we have L, M, N, and from (ii) a, δ are known, and as there are three equations there is no ambiguity.

If R and R_1 are given real quantities, then a and δ are real quantities, but the converse is not necessarily true. If a and δ are given, then from (ii) we have L, M, N, and from the first equation of (iii) we have $\sin R_1$. It may happen that $\sin R_1 > 1$, in which case the instrument cannot be pointed on a, δ. If $\sin R_1 < 1$ there will be two values, R_1 and $180 - R_1$, each of which by substitution in the last two equations of (iii) will give real values for sin R and cos R, so that there will be two methods of pointing the generalised instrument on a given point. This is, of course, the familiar process of reversal in the altazimuth, or of observing upper and lower culmination in the meridian circle.

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3. *A New Form of Divided Object-Glass Telescope.* *By* Sir HOWARD GRUBB, *F.R.S.*

For certain purposes it was necessary to produce a divided object-glass telescope, in which the rays forming the images on one half of the field should be due entirely and solely to the corresponding half object-glass, and the rays forming the other half field to the other half object-glass. Moreover, it was necessary to utilise circular revolving wedges over one of the half object-glasses for the purpose of producing a deviation of the rays in one half field as regards the other; and, furthermore, the images were required to be erect.

These conditions, though theoretically solvable by introducing a thin diaphragm in whose plane the optical axis of the telescope would lie, are not practicable, as the light impinging on this diaphragm at very long incidence introduces false light into the field and destroys the brilliancy of the images.

With this form it is not possible to use circular revolving wedges without a considerable loss of light.

By reversing the two half object-glasses and placing them back to back, the introduction of an effective series of diaphragms is rendered possible without cutting off from the cone of rays which form the images, while the positions of the half object-glasses render the application of circular wedges quite possible and convenient.

With this arrangement the two semicircular pencils of light being each reversed in themselves by the erecting prisms, emerge from the eye-piece as one single disc, just fitting the pupil of the eye with the lower powers.

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4. *The New Spectroheliograph for the Madrid Observatory.* *By* Sir HOWARD GRUBB, *F.R.S.*

The necessary conditions to be fulfilled in designing this spectroheliograph were somewhat limited, owing to the fact that some apparatus (including a 45° prism and a cœlostat) already existing had to be utilised.

Various designs were submitted, and these are mostly described in the Paper. That which was finally accepted did not vary very much, so far as its optical arrangements are concerned, from some of the well-known instruments.

Most of the novel features are to be found in the mechanical arrangements.

The whole instrument, which is very heavy and massive, rests on three feet, sliding on three accurately worked planes.

No slides are used, but the instrument is guided by parallel-motion rods, which rods can be adjusted slightly out of parallelism, so that the instrument, instead of sliding in a perfectly straight line, describes an arc of a circle, of which the object-glass used for forming the sun's image ($22\frac{1}{2}$-foot focus) is the centre, the collimator always pointing to the centre of the object-glass.

Almost the entire weight of the instrument is supported by four steel wires, which hang from counterpoised levers pivoted on the roof of the building, so that only a very small portion of the weight is allowed to bear on the planed surfaces.

The motion is effected by a frictional clock acting on two screws, which drive the instrument simultaneously at the forward and backward ends.

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5. *On the Relation between Intensity of Light, Time of Exposure, and Photographic Action.* *By* Professor H. H. TURNER, *D.Sc., F.R.S.*

1. If I be the intensity of a source of light, and t the time of exposure, it was not unnatural to assume that the photographic effect is proportional to the product It. But experiments have shown that this is not the case. Sir William Abney, who had previously expressed an opinion in favour of the law, announced its 'complete breakdown' under certain conditions in 1893.[1] The conditions specified by him were that a slow plate should be used, more particularly a bromide; and his Paper is written on the assumption that deviation from the law will vary with the kind of plate used.

2. The object of the present note is to suggest that the deviation is, at any rate for stellar work, uniform; that in fact a new law can be formulated, the photographic effect being proportional to

$$I \times t^{0}$$

instead of the first power of t. This result was arrived at by the present writer from a discussion of numerous Greenwich plates in 1905,[2] but as it was supposed to apply merely to particular conditions, no great importance was attached to it. On reviewing the work of the late Mr. R. L. J. Ellery it was noticed that he had arrived at identical figures in 1891,[3] under conditions which probably differed in several essentials from those at Greenwich (*e.g.*, the manufacture of plates has changed a good deal in the interval). It was then remembered that the work of Dr. Schwarzschild, using a quite different method of measuring stellar magnitudes, gave nearly identical results. Finally, on looking up Sir William Abney's paper of 1893 (*loc. cit.*), it was seen that the only numerical result given by him is closely in accord with the suggested formula.

3. As a purely empirical formula, therefore (for at present no physical basis has been suggested, so far as I know), and chiefly with the view of eliciting opinions and experiences which may throw further light on the matter, it is suggested that

$$\text{photographic effect} = \text{intensity} \times (\text{exposure})^{\frac{4}{5}}$$
$$\text{or stellar magnitude} = C - 2{\cdot}5 \log I - 2{\cdot}0 \log t$$

or, with an increase of exposure equivalent to five magnitudes, we only get four.

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6. *Systematic Motion of the Stars.* *By* Professor F. W. DYSON, *F.R.S.*

Eighteen hundred stars from all parts of the sky whose proper motions were greater than 20″ a century were examined. It was found that 1,100 were moving in directions within 60″ of one apex, 600 within 60″ of the second apex, and 100 were outside these limits. The motions of the 100 stars were irregular and not directed to one part of the sky. The number of stars of large proper motion

[1] *Monthly Notices*, liv. p. 65. [2] *Ibid.*, lxv. p. 764.
[3] *Ibid.*, lii. p. 265.

moving to the second apex did not seem in accordance with Mr. Eddington's determination that the stars of the first group were moving in streams, and that the mean velocities of these streams were as 3 : 1. The investigation was not concluded, but showed that stars of large proper motions had apparent drifts to two points in the sky, but a difficulty was presented in the explanation of this as due to two streams.

7. *The Reflecting Telescope and its Suitability for Physical Research.* *By* Sir HOWARD GRUBB, *F.R.S.*

The author referred to a Paper published by him some thirty-one years ago, in which he pointed out the advantage of the reflecting telescope for many branches of physical research, and predicted that the usefulness of the instrument would be appreciated in course of time. For many years after this, instruments of the reflecting type were not in favour either in Europe or America, but experience of recent years of the use of reflectors in the hands of Huggins, Common, Roberts, Wilson, and the astronomers at the Lick Observatory has practically demonstrated the valuable qualities of such instruments for astrophysical research. In America especially many improvements in construction and mounting have been introduced in recent years, which have helped largely to develop the powers and convenience of the reflecting telescope.

Notwithstanding the general impression that the practical limit of size for large telescopes has been reached, and that further developments would be useless on account of the limitations due to imperfections in our atmosphere, the observations and investigations of American astronomers, who have experience of the largest instruments, tend to show that, for physical research, not only would instruments of greater light-grasping power be desirable, but that they are absolutely necessary in order to carry through the work of physical research on the most promising lines.

Those who have had experience with large reflecting telescopes have therefore devoted themselves in endeavouring to grapple with the difficulties which at present hamper the usefulness of such instruments.

This Paper discussed the various devices introduced by the astronomers at Washington, Mt. Wilson, and other observatories possessing large reflectors to overcome the hindrances to increase of aperture due to the want of homogeneity in the air and calorific effects, &c., and discussed the possibilities of increasing the optical power in future instruments.

MONDAY, SEPTEMBER 7.

Discussion on the Theory of Wave-motion,[1] *opened by* Professor HORACE LAMB, *F.R.S.*

[PLATE VII.]

It is understood that one of the chief objects of the discussion is to promote an alliance, or at all events a better understanding, between meteorologists on the one hand and mathematicians on the other, more especially as to the theory of atmospheric waves of various kinds. The need for some such understanding is fairly manifest. There exists a considerable mathematical literature on the subject of waves in fluids, but the theory is far from complete, and the established results are subject to various qualifications which sometimes seriously limit their practical application. It is possible that the theory might be extended in some directions, with a view to meteorology; but the mathematician is deterred from embarking on long and difficult calculations which might in the end prove to have no real bearing on actual phenomena, owing to his own imperfect appreciation of the true atmospheric conditions. The meteorologist, on the other hand,

[1] Ordered by the General Committee to be printed *in extenso.*

confronted with the bewildering complexity of the phenomena which he registers, asks for some theoretical clue which shall help him to analyse these and to reduce them to something like order. In particular he considers that he has indications, in various cases, of distinctly periodic fluctuations of atmospheric pressure, and he requires some corresponding theory. Under these circumstances, perhaps the most useful course will be to attempt a review of such results in the existing theory of wave-motion as may conceivably have an application to meteorological conditions.

We may consider in the first case the oscillations of the atmosphere as a whole. If we assume, for simplicity, isothermal conditions, these are closely analogous to the oscillations of a liquid ocean of uniform depth covering the globe. The velocity of propagation for waves of mainly horizontal displacement is in fact equal to $\sqrt{(g\mathrm{H})}$, where H is the height of the 'homogeneous atmosphere.' If we put $\mathrm{H}=29500$ feet, the most important type of free oscillation on a non-rotating globe has a period of about 16 hours, the type being that of the semi-diurnal tidal oscillation of an ocean of uniform depth. When we take account of the rotation, the modes of oscillation and the periods are considerably modified. The problem is virtually the same as in Laplace's dynamical theory of the tides, with this advantage, that owing to the absence of barriers to the aerial ocean the results are much more closely applicable to the actual circumstances. The calculations of Hough (with the preceding value of H) show that the principal free oscillation has now a period of about 12 hours. This result is of interest in relation to the well-known semi-diurnal variation of the barometer. This is of very regular type, uniform along each meridian, with maxima at 10 A.M. and 10 P.M. An oscillation of this character might (except as to the phase) be regarded as a forced solar semi-diurnal tide, whose period is very nearly coincident with that of one of Hough's free oscillations. This would explain the comparative smallness of the solar diurnal atmospheric tide, and might even be consistent with the smallness of the lunar semi-diurnal tide, since the amplitude of the 'resonance' falls off with extreme rapidity as the difference between the free and forced periods increases. The difficulty is, however, in the phase, which is accelerated instead of retarded. This cannot be accounted for by friction; and the magnitude of the phase-interval also appears far too great to be attributed to such a cause. There seems to be no alternative but to adopt Lord Kelvin's view that the semi-diurnal variation is a temperature effect. The diurnal variation of temperature does not follow the simple harmonic-law, and when analysed by Fourier's method will have constituents whose periods are respectively 1, $\frac{1}{2}$, $\frac{1}{3}$,...of a solar day. The semi-diurnal constituent will be mainly operative owing to approximate coincidence with the free period already referred to. The phase remains to be accounted for, but there does not appear to be any *prima facie* difficulty as to this. It should be mentioned that the forced oscillations due to variation of temperature have been discussed mathematically on the basis of Laplace's theory by Margules.

We have next to consider the possible types of local and (relatively) small scale oscillations of the atmosphere. The most obvious locus of such oscillations is at the common horizontal boundary of two strata of different densities. The circumstances are here very nearly the same as if the fluids were incompressible, and we may quote Stokes' formula for the velocity of propagation of waves on the common boundary between two liquids in equilibrium, viz.:—

$$\mathrm{V}=\sqrt{\left\{\frac{g\lambda}{2\pi}\cdot\frac{\rho-\rho'}{\rho+\rho'}\right\}},$$

where λ is the wave-length, and ρ, ρ' are the densities of the lower and upper fluids respectively. When $\rho'=0$, we have $\mathrm{V}=\sqrt{(g\lambda/2\pi)}$ as in the ordinary theory of deep-water waves; in the present case the potential energy of a given deformation is diminished in the ratio $(\rho-\rho')/\rho$, whilst the inertia is increased in the ratio $(\rho+\rho')/\rho$. When $\rho-\rho'$ is relatively small, the oscillations are exceedingly slow, as in the case of a flask half-filled with oil and half with water, a phenomenon noticed long ago by Franklin. On the other hand, such waves are easily produced, owing to the smallness of the potential energy. An interesting application of the theory has in recent times been made by W. V. Ekman, to explain the abnormal resistance which is occasionally experienced by ships off the mouths of various Norwegian fiords, where a layer of fresh water rests on one of salt water. This is interpreted as a wave-resistance due to waves generated on the common boundary. If ρ' is greater than ρ, the wave-velocity is imaginary: there is then of course instability, and a corrugation of wave-length λ, once produced, will tend to increase in amplitude, and the more rapidly the smaller the value of λ. This has a bearing on the theory of the formation of cirrus clouds, which was proposed and experimentally illustrated by Jevons in 1857. An upper layer of air is supposed to cool by radiation until it becomes heavier than the air below it; a sort of interpenetration then takes place by means of narrow filaments which are made manifest by the condensation of vapour when the warmer air comes in contact with the cooler.

In practice a discontinuity of density in the atmosphere is likely to be accompanied by a discontinuity of velocity. The corresponding circumstances in the case of incompressible fluids were investigated by Lord Kelvin; if the velocities of the two currents are v, v', the formula for the wave-velocity may be written:—

$$V = \frac{\rho v + \rho' v'}{\rho + \rho'} \pm \sqrt{\left\{\frac{g\lambda}{2\pi} \cdot \frac{\rho - \rho'}{\rho + \rho'} - \frac{\rho\rho'}{(\rho + \rho')^2}(v - v')^2\right\}},$$

or, in case the difference of density is relatively small,

$$V = \tfrac{1}{2}(v + v') \pm \sqrt{\left\{\frac{g\lambda}{2\pi} \cdot \frac{\rho - \rho'}{2\rho} - \tfrac{1}{4}(v - v')^2\right\}}.$$

The first term represents the mean velocity of the two currents; the second represents a wave-velocity which may be superposed on this in either direction. This second term is imaginary, indicating instability, for values of λ less than

$$\frac{2\pi\rho}{\rho - \rho'} \cdot \frac{(v - v')^2}{2g}.$$

Under atmospheric conditions very great wave-lengths will be required for stability, unless $v - v'$ is very small. The importance of the fact that with an absolute discontinuity of density the slightest difference of velocity would imply partial instability has been strongly emphasised by Helmholtz. He pointed out that in the case of air a rapid mixture of the two strata must take place, and that this cause is far more powerful than friction in establishing a transition stratum within which the change of density from ρ to ρ' takes place gradually. The presence of such a layer would modify the theory to some extent, but this has hardly yet been investigated.

The theoretical results so far quoted relate to disturbances of infinitely small amplitude; in cases of instability they represent therefore only the initial tendency. Helmholtz has shown that although a plane surface of separation between two currents is unstable, there are other forms of relative equilibrium which are possibly stable. Since any common velocity may be superposed on the two currents without affecting the dynamics of the question, this amounts to a theory of waves of finite (as distinguished from infinitely small) amplitude. The calculations, which are somewhat complicated, have been revised by W. Wien; but it does not appear yet to have been decisively settled whether, or in what sense, such waves may be stable. It is very desirable that this very interesting and definite problem should be attacked *de novo* by some mathematician. Helmholtz argues that the theory has a real application to the atmosphere, and that the crests of these waves are under favourable conditions made visible by the condensation of vapour cooled by expansion.

It will be evident from this review that the theory of wave-motion is, from the point of view of atmospheric phenomena, on many points uncertain. It may perhaps be urged that it would be unfair to expect any great improvement in this respect until the various conditions which actually prevail in the atmosphere have been more thoroughly explored. Fortunately, the progress which is now being made in the study of the upper regions of the air encourages us to hope that before long we may have more secure data to form the basis and the criterion of future theoretical investigations.

Dr. SHAW expressed his appreciation of the clearness of Professor Lamb's paper and of the advantages for the study of the atmosphere likely to accrue from having the results obtained by mathematical investigation put together in a concise and easily accessible form. So far as the atmospheric oscillations of short period were concerned it was not easy to accept an explanation depending upon the assumption of a substantial discontinuity of velocity between consecutive horizontal layers. There was plenty of evidence of stratification in the atmosphere of one sort or other, but pressure, being an integral gravitational effect, could not show discontinuous stratification. Consequently there could not be a discontinuous change of horizontal pressure-gradient. There might be slight discontinuous stratification as regards temperature, and consequently also as regards density; but, as regards wind velocity, anything of the nature of a persistent wind current in the upper air would have its velocity governed by the pressure gradient and the density, and the discontinuity would be limited to the extent of that shown in the density, which can very rarely reach so great a proportional magnitude as 3 per cent.

The records obtained from autographic instruments occasionally showed undulations, more or less sinusoidal in character, which had not hitherto been explained. Neither the proximate cause of the initial disturbance, nor the oscillating system which was set in vibration thereby, had been identified. Such approximately sinusoidal oscillations were sometimes found in the wind, as shown in the example taken from the Southport Observatory records for January 12, 1907 (see Plate VII.), but more frequently in the barometric pressure, and particularly in the records of the 'microbarograph,' an instrument which, as ordinarily adjusted, magnifies rapid variations of pressure twentyfold, as compared with the mercury barometer, but disregards slow changes altogether. A period of about twenty minutes is frequently to be identified in the records, and the trace from Mr. Dines's microbarograph at Oxshott for February 22–23, 1904, reproduced in the original paper,[1] shows intermittent groups of oscillations lasting for about twenty hours, commencing with a period of about half an hour and ending with a period of about ten minutes.

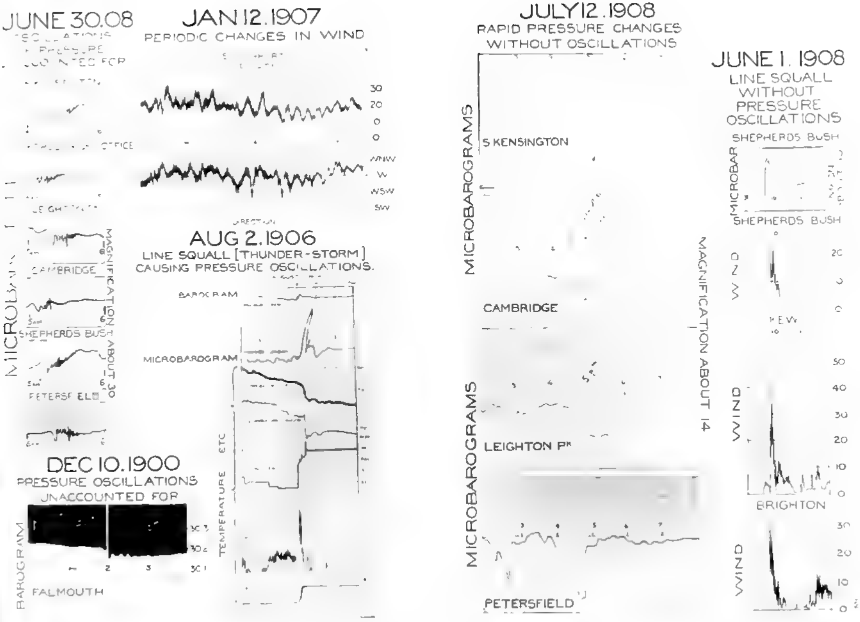
Barometric oscillations were occasionally set up during the violent commotion of the line squall which introduces a thunderstorm. A good example is given in the microbaric trace for August 2, 1906 (see Plate VII.), where an oscillation with rapid damping is clearly indicated. The changes in the other elements are reproduced in order to indicate the general violence of the commotion.

But 'line-squall' or thunderstorm changes do not always cause oscillations. The microbarographic trace for June 1, 1908 (see Plate VII.), shows a sudden rise of pressure as usual (the crochet d'orage or Gewitter-nase), but no recognisable undulations; although the sudden violence of the wind is very conspicuous in the records, and was still more so in reality on account of the destruction of trees caused by it in Bushy avenue.

Another example was given of violent barometric fluctuations on July 12, 1908, which were recorded during thundery weather, but without producing undulations or indeed any other notable effects.

On the other hand, there were examples of regular undulations set up without any considerable barometric change, the most noteworthy of which was the succession of four undulations, commencing with a range of about five-thousandths of an inch, lasting about a quarter of an hour, and then violently interrupted by a sudden, though slight, explosive disturbance which set up different and much faster oscillations for a similar interval. Traces of this train of atmospheric waves from five

[1] *Q.J. Roy. Met. Soc.*, vol. xxxi. 1905, p. 39. For a discussion of the theory of the instrument, see Chrystal, *Proc. R.S.E.*, vol. xxviii. 1908, p. 437.



JUNE 30.08
JAN 12.1907
PERIODIC CHANGES IN WIND
30
20
0
0
WNW
W
WSW
SW
CAMBRIDGE
SHEPHERDS BUSH
MICROBAROGRAMS
MAGNIFICATION ABOUT 30
AUG 2.1906
LINE SQUALL [THUNDER-STORM]
CAUSING PRESSURE OSCILLATIONS.
BAROGRAM
MICROBAROGRAM
TEMPERATURE ETC
DEC 10.1900
PRESSURE OSCILLATIONS
UNACCOUNTED FOR
BAROGRAM
FALMOUTH
JULY 12.1908
RAPID PRESSURE CHANGES
WITHOUT OSCILLATIONS
MICROBAROGRAMS
S KENSINGTON
CAMBRIDGE
MAGNIFICATION ABOUT 14
MICROBAROGRAMS
LEIGHTON B^D
PETERSFIELD
JUNE 1. 1908
LINE SQUALL
WITHOUT
PRESSURE
OSCILLATIONS
SHEPHERDS BUSH
MICROBAR
SHEPHERDS BUSH
WIND
KEW
WIND
50
40
30
20
10
0
BRIGHTON
WIND
30
20
10
0

stations, viz., Cambridge, South Kensington, Westminster, Shepherd's Bush, and Leighton Park, Reading, were exhibited (see Plate VII., June 30). Another, Petersfield (Ditcham Park), has been added. The distance apart between Cambridge and Petersfield is about 130 miles. The record for the hour 5 A.M. to 6 A.M. for each place is reproduced. There is barely a quarter of an hour shown between the occurrence of the trough of the first wave at any of the places. No great stress can be laid on the accuracy of timing, and the South Kensington record in particular appears to be mistimed. In any case, it would seem that the disturbance, if not simultaneous at the different places, travelled faster than 100 miles per hour.[1]

One other example of very regular oscillations was shown, namely, that of the photographic record of the Falmouth barogram for December 10, 1900 (see Plate VII.). The undulations, in this case also subject to damping, are clearly shown in the reproduction.

The problem presented by these examples was to determine whether the oscillations were due to the vibrations of the atmosphere as a whole or in part, and, in the latter case, to specify what part. It was necessary again, as the late Lord Salisbury said about the luminiferous ether at Oxford, to find a nominative case to the verb to undulate.

Professor Lamb had suggested only gravitational and vertical wave-motion in an atmosphere stratified in discontinuous layers. The question was asked whether it was possible that a steady atmospheric current of wind, with its transverse pressure gradient and its great momentum, could take on an elasticity for transverse vibrations in consequence of the quasi-rigidity of its motion relative to the earth's axis, and thus form a system capable of horizontal oscillations with associated pressure changes.

Professor C. H. Lees pointed out that since Dr. Shaw's observations showed that when there was a sudden change of atmospheric pressure it was at times followed by an oscillation of pressure, and at other times not, it looked as if we were dealing with an oscillatory system in which the damping term due to viscosity had nearly the critical value, and in which, therefore, a small change of viscosity would lead on the one hand to oscillation, on the other to no oscillation.

Professor A. Lawrence Rotch, Director of Blue Hill Observatory, U.S.A., said that the waves set up in the atmosphere during thunderstorms were of common occurrence at Blue Hill. But another class of waves, arising from different conditions, was discussed by Mr. H. H. Clayton in vol. xl. part iii. of the 'Annals of the Astronomical Observatory of Harvard College.' These waves occur to the north-eastward of a cyclonic storm moving north-east, and the same wave has been traced on the barographs of stations situated several hundred miles apart, the velocity of propagation of the wave from west to east being somewhat greater than the motion of the cyclone centre itself. As a rule, oscillations in wind velocity and direction are synchronous with the barometric waves, the wind reaching a maximum velocity from a northerly direction during the passage of the crest of the wave and a maximum velocity from an easterly direction in the trough of the wave. Nearly all the waves occur in rainy weather, and usually there is an increase in the intensity of the rainfall at the wave-crest. That similar waves occasionally exist in the upper air is shown by the undulations seen in clouds. According to a study of special cloud-forms at Blue Hill by the late Mr. A. E. Sweetland, published in the 'Annals of the Astronomical Observatory of Harvard College,' vol. xlii. part i., the greatest number of undulations are observed in the cirrus and cumulus levels. At the lower level they occur to the north-east of the cyclone centre and precede warmer weather, being due to a warm current flowing over a colder current near the ground, a condition which Von Helmholtz has shown to be necessary to the formation of undulatory clouds,

[1] In considering these and the other traces of the microbarograph, it should be remembered that the recording pen is carried by a lever and describes a circle. In some of the traces the effect of the curvature of the ordinates is very marked, and in the Shepherd's Bush record of June 30 there is a gradual rise of the pen during the period attributable to temperature change.

and the existence of which the kite-flights at Blue Hill have demonstrated. Sometimes there are coincident rhythmical oscillations in the barograph trace. The continuous crests and hollows of the undulations in the clouds extend usually from north to south, or at right angles to their drift, in contrast to the cirrus bands, which move most frequently in the direction of their length. Since the crest of a wave usually lies normal to the wind which produces and propagates it, these observations confirm Von Helmholtz's explanation of the undulations as being the visible crests of atmospheric waves formed between currents of air differing in density and also in velocity or direction.

Sir Oliver Lodge asked whether the recurrent rapid minor oscillations of brief duration could not be due to a sort of echo or reverberation from the discontinuity layers; but subsequently he supposed that they might more likely be due to secondary and insignificant vortices accompanying the main depression.

Sir William White observed that his interest in wave-motion chiefly centred in water waves, and particularly in deep-sea waves. Observations of ocean waves were of importance to the naval architect, since the behaviour of ships at sea largely depended upon the character of the wave-phenomena, and particularly upon the proportion of the relative periods of approach of waves and the natural periods of oscillation of ships. For many years (under orders from the Admiralty) officers of the Navy made numerous observations of the dimensions and periods of waves which produced oscillations in ships—particularly transverse oscillations of rolling—noting at the same time the actual angles of inclination obtained on each side of the vertical. In this manner the modern theory of rolling (developed chiefly by the late William Froude and Professor Rankine) was confirmed to an extent sufficient for practical purposes. In the case of the 'Challenger Expedition also special orders were given in regard to making observations of wave-phenomena; but, unfortunately, very little additional information was obtained. There is need for much more extended observation of ocean waves, particularly under the special circumstances when they form a fairly regular series. The phenomena of a 'confused sea' also require much more extensive study. In addition, the behaviour of deep-sea waves during their degradation, when they run into shallow water and approach the shore, deserves careful study, and has a practical application in regard to the construction of harbours and sea defences of all kinds.

Up to the present time we have but little definite information available in regard to the generation of waves, and the laws connecting the force and velocity of wind with the creation of water-waves. The best observations available are those of the late Lieutenant Paris, of the French Navy, and they reflect the greatest credit upon that officer both as to the methods employed and extent of the work done. The analysis of his results, however, shows conclusively that much more extended observation is required.

Wave-phenomena which accompany the movements of ships through water which otherwise would be still, have received great attention in recent years in connection with experiments made on models in tanks on the system introduced by the late Mr. William Froude, greatly developed in this country by Mr. R. E. Froude, and now extensively employed in all maritime countries as an aid to the design of steamships. This branch of investigation is still in full progress, and it cannot be doubted that wave-phenomena in general may be studied with advantage in such tanks. In most of these establishments the pressure of work in connection with experiments which have a direct bearing upon the designs of new steamships interferes greatly with purely research work. On these grounds it has been advocated for some years past to establish at the National Physical Laboratory an experimental tank, which should be devoted primarily to research work. The Institution of Naval Architects has made various attempts towards the creation of such an establishment, but has failed hitherto. Quite recently—thanks to the generosity of Mr. Alfred Yarrow in offering to meet the capital expenditure required—the question has been brought into a much more hopeful condition. The Institution of Naval Architects is now engaged in obtaining guarantees from shipbuilders and shipowners for an adequate fund to meet the charges involved in the maintenance and working of an experimental tank at Bushey, and there is good hope of success; as well as of the readiness of the Executive Committee of the Laboratory to permit the tank to be placed at Bushey. It may be hoped, therefore, that before long we shall have in this country an establishment in which experimental investigations of wave-phenomena in water may be carried further than has yet been possible; and it must be the conviction of all those who have given attention to the subject that, whether wave-phenomena in water or in the atmosphere be the special subject of study, the foundation of a sound theory must be laid by means of experimental inquiries, to the results of which mathematical processes may be applied in order to establish a comprehensive theory.

Professor Larmor, Professor Trouton, and M. Teisserenc de Bort also contributed to the discussion.

Department of Mathematics.

The following Papers were read:—

1. *Linear Vector Functions.* *By* Sir Robert Ball, *F.R.S.*

The results here given are based upon and are largely identical with those obtained by the late Professor C. J. Joly, to whom the application of quaternions to the theory of screws is almost entirely due. The author was in intimate correspondence with Professor Joly for many years, and up to the time of his lamented death the subjects now referred to were under constant discussion. The present communication is now offered in Joly's own university as a token of affectionate remembrance. The occasion is the more appropriate as Joly was one of the successors to the chair of Hamilton, whose invention of linear vector functions was one of the most wonderful strokes of quaternion magic.

Let λ_1, ω_1; λ_2, ω_2; λ_3, ω_3 be three pairs of vectors defining three screws. Let t_1, t_2, t_3 be the intensities of three wrenches on those screws. These wrenches compound into a single wrench of intensity t on a screw $\lambda_1\, \omega$ of the three system, and we have

$$t\lambda = t_1\lambda_1 + t_2\lambda_2 + t_3\lambda_3 \quad . \quad . \quad . \quad . \quad . \quad (\text{i})$$

$$t\omega = t_1\omega_1 + t_2\omega_2 + t_3\omega_3 \quad . \quad . \quad . \quad . \quad . \quad (\text{ii})$$

Multiplying the first by $V\lambda_2\lambda_3$ and taking the scalar

$$t\, S\lambda\lambda_2\lambda_3 = t_1 S\lambda_1\lambda_2\lambda_3,$$

by this and the two similar equations we have from (ii)

$$\omega = (\omega_1 S\lambda\lambda_2\lambda_3 + \omega_2 S\lambda\lambda_3\lambda_1 + \omega_3 S\lambda\lambda_1\lambda_2)/S\lambda_1\lambda_2\lambda_3.$$

But the expression on the right-hand side is a linear vector function $\phi\lambda$ of the most general type.

We thus obtain λ, $\phi\lambda$ as the two vectors defining in the most general manner all the screws of a three-system. We now show how the properties of such a system are obtained at once as properties of linear vector functions.

One of Hamilton's most remarkable propositions states that

$$\phi V\phi'\mu\phi'\nu = mV\mu\nu.$$

This is the quaternion statement of the fact that of two reciprocal three systems A and B each screw of A is reciprocal to each screw of B.

If $\phi\lambda$, λ represent a three system, then any screw $-mV\mu\nu$, $V\phi\mu\phi\nu$ will be a screw of the reciprocal system, whatever λ, μ, ν may be, provided that m is the invariant of the linear vector function defined by the equation

$$S\phi\lambda\phi\mu\phi\nu - mS\lambda\mu\nu = 0.$$

To prove this it is only necessary to write the equation of reciprocity

$$S(\phi\lambda V\phi\mu\phi\nu) - mS\lambda V\mu\nu = 0$$

or

$$S\phi\lambda\phi\mu\phi\nu - mS\lambda\mu\nu = 0.$$

It was shown by Joly that the screws reciprocal to $\phi\lambda$, λ must form the three system $-\phi'\lambda$, λ. But we have also shown that $-mV\mu\nu$, $V\phi\mu\phi\nu$ by varying μ and ν will form the system reciprocal to $\phi\lambda$.

Hence if we operate on $V\phi\mu\phi\nu$ with $-\phi'$ we must come to $-mV\mu\nu$, or

$$\phi' V\phi\mu\phi\nu = mV\mu\nu$$

which may be written

$$\phi V\phi'\lambda\phi'\mu = mV\lambda\mu.$$

This shows that $V\phi'\lambda\phi'\mu$ is a linear vector function of $V\lambda\mu$.

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2. *The Inductance of Two Parallel Wires.*
By J. W. Nicholson, *D.Sc., B.A.*

When direct and return currents flow in two wires of great length, and the alternation is not rapid, the effective self-induction L per unit length of the system may be calculated readily by simple integration.[1]

If the wires have radii (a, b) and permeabilities (μ, ν), and if c be the distance between their axes,

$$L = 2 \log \frac{c^2}{ab} + \frac{1}{2}(\mu + \nu).$$

But this formula is generally of little practical use when the frequency of alternation is several thousands per second. Such frequencies are of constant use in practical work, where pairs of long wire leads are continually employed, whose self-induction must be small. A knowledge of the effective self-induction of such leads is therefore very desirable. The general case presents considerable mathematical difficulty, but the solutions given below appear to include most cases of practical utility.

The mode of proof depends chiefly upon a transformation of a series of Bessel functions of type K_n finite at infinity, to another series similarly related with respect to a new origin. The disturbances caused by one wire in the vector potential due to the other may be summed to a high order of accuracy. From a knowledge of the vector potential, the total current in each wire, and thus the self-induction, may be deduced.

The result for wires not too close together is

$$L = 2 \log \frac{c^2}{ab} + \frac{2\mu}{x} \cdot \frac{\operatorname{ber} x \operatorname{ber}' x + \operatorname{bei} x \operatorname{bei}' x}{(\operatorname{ber}' x)^2 + (\operatorname{bei}' x)^2}$$
$$+ \frac{2\nu}{y} \cdot \frac{\operatorname{ber} y \operatorname{ber}' y + \operatorname{bei} y \operatorname{bei}' y}{(\operatorname{ber}' y)^2 + (\operatorname{bei}' y)^2},$$

where (μ, ν) are the permeabilities of the wires, (σ, σ') their resistivities.

$$x = 2a\sqrt{\frac{\pi\mu n}{\sigma}}, \quad y = 2b\sqrt{\frac{\pi\nu n}{\sigma'}}.$$

and ber x, bei x are the functions introduced by Lord Kelvin, and afterwards tabulated. Their main properties are well known to mathematical electricians.

In this result, the greatest possible error is of magnitude n^2c^2/v^2 relative to unity, where $v = 3.10^{10}$. For two wires one centimetre apart, and with a frequency

[1] Russell, *Alternating Currents*, i. p. 56.

so great as a hundred millions per second, this becomes 4.10 ^{4}. When the wires are close together, an extra term R must be added to L. For two wires equal in all respects, R is the real part of

$$4\frac{a^2}{c^2} \cdot \lambda_1 \cdot \left(\log \frac{a}{c} - \frac{\mu J_0}{kaJ_0'}\right) \Big/ \left(\log \frac{na}{v} - \frac{\mu J_0}{kaJ_0'}\right),$$

where
$$\lambda_1 = \left(1 - \frac{\mu J_1}{kaJ_1'}\right) \Big/ \left(1 + \frac{\mu J_1}{kaJ_1'}\right)$$

and the argument of the Bessel functions is in all cases

$$ka = xi^{\frac{3}{2}} = 2a\sqrt{\frac{\pi\mu n}{\sigma}} \cdot \left(\frac{-1}{\sqrt{2}}\right).$$

This neglects a term of order $\left(\frac{a}{c}\right)^4$, and may be used practically with sufficient accuracy even when $c = 3a$.

If the wires are very far apart, so that, although n^2a^2/v^2 is negligible, n^2c^2/v^2 is not, then, subject to an error of order n^2a^2/v^2 relative to unity,

$$L = 2Y_0\left(\frac{nc}{v}\right) - 4\left\{\log\frac{nc}{2v} + \cdot 577\right\} + \frac{4\mu}{x} \cdot \frac{\text{ber}\,x\ \text{ber}'\,x + \text{bei}\,x\ \text{bei}'\,x}{(\text{ber}'\,x)^2 + (\text{bei}'\,x)^2}$$

where γ_0 is the ordinary Bessel function of zero order of the second kind, defined by

$$Y_0(x) = \left\{\frac{\partial J_n(x)}{\partial n} - (-)^n \frac{\partial J_{-n}(x)}{\partial n}\right\}_{n=0}$$

whose tabulation is well known.

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3. *On the Ether Stress of Gravitation.* *By* Professor F. PURSER, *F.T.C.D.*

The problem of which Maxwell first attempted the solution, of accounting for gravitation by a stress of the ether, is that of solving the equations

$$\begin{aligned}
\frac{dA}{dx} + \frac{dH}{dy} + \frac{dG}{dz} &= -\rho \cdot \frac{dV}{dx} \\
\frac{dH}{dx} + \frac{dB}{dy} + \frac{dF}{dz} &= -\rho \cdot \frac{dV}{dy} \qquad \qquad (1) \\
\frac{dG}{dx} + \frac{dF}{dy} + \frac{dC}{dz} &= -\rho \cdot \frac{dV}{dz}
\end{aligned}$$

ρ being the density of gravitating matter, V the gravitation potential, A, B, C, F, G, H, according to Dr. Williamson's notation, the six components of stress. Substituting for ρ $-\frac{1}{4\pi}\nabla^2 V$, it is easily seen that these become

$$\begin{aligned}
\frac{dA}{dx} + \frac{dH}{dy} + \frac{dG}{dz} &= \frac{dA'}{dx} + \frac{dH'}{dy} + \frac{dG'}{dz} \\
\frac{dH}{dx} + \frac{dB}{dy} + \frac{dF}{dz} &= \frac{dH'}{dx} + \frac{dB'}{dy} + \frac{dF'}{dz} \qquad \qquad (2) \\
\frac{dG'}{dx} + \frac{dF}{dy} + \frac{dC}{dz} &= \frac{dG'}{dx} + \frac{dF'}{dy} + \frac{dC'}{dz}
\end{aligned}$$

where

$$A' = \frac{1}{8\pi}\left(\left[\frac{dV}{dy}\right]^2 + \left[\frac{dV}{dz}\right]^2 - \left[\frac{dV}{dx}\right]^2\right) \quad H' = -\frac{1}{4\pi}\frac{dV}{dx}\frac{dV}{dy}$$

$$B' = \frac{1}{8\pi}\left(\left[\frac{dV}{dz}\right]^2 + \left[\frac{dV}{dx}\right]^2 - \left[\frac{dV}{dy}\right]^2\right) \quad F' = -\frac{1}{4\pi}\frac{dV}{dy}\frac{dV}{dz}$$

$$C' = \frac{1}{8\pi}\left(\left[\frac{dV}{dx}\right]^2 + \left[\frac{dV}{dy}\right]^2 - \left[\frac{dV}{dz}\right]^2\right) \quad G' = -\frac{1}{4\pi}\frac{dV}{dz}\frac{dV}{dx}$$

Maxwell now solves these by taking A, B, C, F, G, H = A′, B′, C′, F′, G′, H′, corresponding, as he shows, and as is easily seen, to a compression $\frac{R^2}{8\pi}$ along the lines of gravitating force, the astronomical unit of mass being employed, accompanied by an equal tension perpendicular to these lines, R being the resultant force of gravitation on unit mass. This, then, he considers, is the given state of stress in the ether, for which we have to account, if possible, by a corresponding state of strain. This now it is impossible to effect for an arbitrary distribution of gravitating matter for an ether homogeneous and either isotropic or eolotropic, according to a given Greenian function.

The difficulty will, however, be removed if we consider that we are not bound to Maxwell's special solution of the equations (1) or their equivalents (2), but are free to take such a solution as may be deduced from a state of strain according to the laws for, say, an homogeneous isotropic ether. Such solution will then yield on an element volume the same resultant force as the Maxwellian stress. Now it is seen that we may make use, with slight modification, for this purpose of the formula given by Lord Kelvin for an indefinite homogeneous isotropic medium on which given bodily forces act per unit of mass. We thus find the following displacement expressions:

$$u = n \,.\iiint \frac{\rho' \dfrac{dV}{dx'}\, dx'dy'dz'}{r}$$

$$+ \bar{n}\frac{d}{dx}\iiint \frac{\rho'\left((x'-x)\dfrac{dV'}{dx'} + (y'-y)\dfrac{dV}{dy'} + (z'-z)\dfrac{dV}{dz'} - dx'dy'dz'\right)}{r}$$

with analogues for v, w, where

$$r = \sqrt{(x-x')^2 + (y-y')^2 + (z-z')^2},$$

and the integrals are taken throughout the space occupied by gravitating matter, n, $\bar{n}$, being certain functions of λ, μ for the ether. The state of stress derived from these according to the laws of a homogeneous isotropic medium will be the required ether stress of gravitation.

It is evident that the ether stress corresponding to a given electrostatic field can be investigated on the same lines.

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4. *Conservative Systems of Prescribed Trajectories.* *By* Professor E. Odell Lovett.

Tisserand in the first volume of his classic treatise on celestial mechanics studies the problem of determining the forces under which a particle, whatever be its initial position and velocity, always describes a conic section whose equation is taken in its most general form. Bertrand[1] was the first to set the problem; he solved it, and later Darboux and Halphen in more complete form.[2]

[1] *Comptes Rendus*, vol. lxxxiv. pp. 671, 731. [2] *Ibid.*, pp. 760, 939.

Battaglini[1] determined the components of the forces in the case of motion in a conic; and Dainelli, in the eighteenth volume of Battaglini's 'Journal,' treated the more general one of finding the components of the forces acting on the particle as functions of its co-ordinates when the trajectory is a general curve. In a recent number of Crelle's 'Journal,' vol. 131, pp. 136–151, Professor Stephanos has proposed still another generalisation of Bertrand's problem. Bertrand considered the case where the force has, in general, a unique direction at every point and the trajectories are conic sections; he proved that in this case the force should either pass through a fixed point or remain parallel to a fixed direction. Professor Stephanos examines the general case of conic section trajectories when the force has not necessarily a unique direction at every point; he finds that this more general problem admits of no other solution than those included in the case considered by Bertrand, and he shows that every force under which a point describes a conic section, whatever be the initial conditions, either always passes through a fixed point or remains parallel to a fixed direction; finally, by applying his method to the determination of the explicit forms of the forces in the case of conic sections, Stephanos rediscovers the known results due to Darboux and Halphen.

All these discussions have been concerned with the motion of a single material point. Similar problems may be proposed for material systems. Oppenheim, in the third volume of the 'Publications' of the Von Kuffner Observatory, investigates the central conservative forces under which three bodies describe given co-planar curves; he constructs the analytical machinery for the case of three arbitrary orbits, but the resulting differential equations offer insuperable difficulties, and the only particular solutions realised were previously known.

The first section of the present paper offers a modest contribution by studying the problem of Bertrand, in all the generalities considered by Stephanos, but for trajectories which include the conic sections as a very special case. In the second section a wider generalisation is undertaken by proposing to determine the forces capable of maintaining the motion of a particle on an arbitrarily given curve, in space of any dimensions, independently of the initial conditions of the motion. In the third section the forces of a central conservative system, capable of maintaining a system of m-particles in motion on as many prescribed, but arbitrary, orbits in a space of n-dimensions are investigated. In the succeeding sections applications are made to the study of a system of three bodies describing any given trajectories in ordinary space, independently of the initial conditions, under central conservative forces. Of special interest, perhaps, is a system of differential equations which the functions, defining the orbits, must satisfy, if the velocities and accelerations are to be determinate, certain of these equations vanishing identically when the motions take place in a single plane; and among the results achieved in the plane is the construction of an infinite family, involving arbitrary functions of integrable problems of three bodies, whose force-functions depend only on the masses and the mutual distances of the bodies.

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5. *Factorisation of the A.P.F. of $N=(y^n \mp 1)$.*
By Lieut.-Colonel ALLAN CUNNINGHAM, *R.E.*

Here A.P.F. is short for 'maximum algebraic prime factor.'

Let F (n) denote the A.P.F. of N $(n) = (y^n \mp 1)$.

$$\text{Then } N(105) = F(105) \, . \, F(35) \, . \, F(21) \, . \, F(15) \, . \, F(7) \, . \, F(5) \, . \, F(3) \, . \, F(1),$$

$$\text{whereof } F(105) = \frac{N(105) \, . \, N(7) \, . \, N(5) \, . \, N(3)}{N(35) \, . \, N(21) \, . \, N(15) \, . \, N(1)},$$

the signs $\mp$ being the same as in N (105) throughout, and is of order y^{48}.

[1] *Giornale di Matematiche*, vol. xvii. p. 43 *et seq.*

Also F (105) is (algebraically) resolvable into two large factors, say L, M, in following cases:—

$$\text{Of } (y^{105}+1), \text{ when } y=3\eta^2, 7\eta^2, 15\eta^2, 35\eta^2$$
$$\text{Of } (y^{105}-1), \text{ when } y=5\eta^2, 21\eta^2, 105\eta^2$$

and each factor L, M is of order y^{24}, and is susceptible of the six 2^{ic} partitions $(t^2+\lambda u^2)$, $(t'^2-\lambda' u'^2)$, where $\lambda=3, 7, 35$; $\lambda'=5, 21, 105$.

The values of the large factors L, M of F (105) are shown below—resolved into their prime factors as far as found practicable—for the small base $y=3, 5, 7, 12$.

N (105)	L and M of F (105)
$(3^{105}+1)$;	L = 24151 . 3369031 ; M = 211 . 1051 . 3454081 ;
$(5^{105}-1)$	L = 21, 226, 783, 250, 214, 361*
	M = 207, 468, 970, 805, 907, 721*
$(7^{105}+1)$	L = 211 . 338, 640, 865, 331, 157, 691†
	M = 450, 798, 894, 542, 150, 330, 401 ; †
$(12^{105}+1)$	L = 46, 199, 145, 931, 519, 207, 045, 842, 151†
	M = 1471 . 85, 890, 295, 500, 577, 151, 086, 861†

The composition of the large factors in the L, M above is unknown; but those marked * contain no factors < 100,000, and those marked † contain no factors < 10,000.

The complete factorisation (into prime factors) of the seven algebraic sub-factors of the above N (105), viz., of

$$(y \mp 1), (y^3 \mp 1), (y^5 \mp 1), (y^7 \mp 1), (y^{15} \mp 1), (y^{21} \mp 1), (y^{35} \mp 1)$$

is known for each of the above bases [$y=3, 5, 7, 12$], except that of $(12^{35}+1)$.

6. *An Elementary Discussion of Schläfli's Double-six.* *By* Professor A. C. Dixon, *Sc.D., F.R.S.*

The object of this note was to discuss by elementary methods the system of twelve straight lines in space known as a double-six. The lines lie on a cubic surface,[1] but no reference is made to this fact.

Let a be a given straight line and 2, 3, 4, 5, 6 five other lines meeting it in a_2, a_3, a_4, a_5, a_6 respectively. Each of the five tetrads 3456, 2456, 2356, 2346, 2345 is met by a second line; let these be b, c, d, e, f, so that b meets 3, 4, 5, 6 in b_3, b_4, b_5, b_6 respectively, and so on. The theorems to be proved are these:—

1. The five lines b, c, d, e, f all meet another line, to be called 1.
2. The pairs of planes connecting b with a_3, c_2; a_4, d_2; a_5, e_2; a_6, f_2 are in involution: there are sixty relations of this type. This theorem includes (2′), that $(c_2 d_2 e_2 f_2)=(a_3 a_4 a_5 a_6)$.
3. If the intersection of the planes $a2$ and $b1$ is called (12), and so on, the lines (12) (34) (56) lie in a plane: of such planes there are fifteen.

The theorem (2) is new to me; the others are known in the theory of the cubic surface.

[1] Salmon, *Geometry of Three Dimensions*, 4th edit., p. 500. Mr. Richmond has lately drawn attention to the double-six, *Camb. Phil. Proc.*, vol. xiv. p. 475. For an elementary discussion of the generators of a hyperboloid, without reference to the surface, see a paper in this year's *Proceedings of the Edinburgh Mathematical Society*.

7. *On the Logarithmic Case in Linear Differential Equations.* *By* Professor A. C. DIXON, *Sc.D., F.R.S.*

If X is a linear differential operator whose coefficients are functions of the independent variable x it is commonly possible to solve the equation

$$Xy = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

by finding a function $\phi(m, x)$ of x and a parameter m, such that

$$X\phi(m, x) = f(m) \cdot \psi(m, x) \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where ψ is a function that is finite in general, and then choosing m so that $f(m) = 0$ and $\phi(m, x)$ is not identically 0.

When the equation $f(m) = 0$ has a repeated root a solution may generally be derived by differentiating ϕ with respect to m, and it is my present object to justify this proceeding in a very simple way.

Differentiate (2) with respect to m; then, since m does not appear in X,

$$X\frac{\partial}{\partial m}\phi(m, x) = f'(m)\psi(m, x) + f(m)\frac{\partial}{\partial m}\psi(m, x)$$

so that if $f(m)$, $f'(m)$ are zero

$$\frac{\partial}{\partial m}\phi(m, x)$$

is a solution of (1), as well as $\phi(m, x)$.

The simplest case is when X has constant coefficients and may be written F(D). Then

$$F(D)e^{mx} = f(m)e^{mx}$$

and by differentiating as to m

$$F(D)xe^{mx} = f'(m) \cdot e^{mx} + f(m) \cdot xe^{mx}$$

so that e^{mx}, xe^{mx} are both solutions of $F(D)y = 0$ if m is a repeated root of $f(m) = 0$.

In the very general case when

$$X \equiv F_0(xD) + x^r F_1(xD) + x^{2r} F_2(xD) + \ . \ . \ .$$

the procedure is to form the series

$$\sum_{k=0}^{\infty} A_k x^{m+kr} = \phi(m, x)$$

where $A_0 = 1$, and

$$A_k F_0(m + kr) + A_{k-1} F_1(m + kr - r) + \ . \ . \ . \ = 0 \ (k = 1, 2, \ . \ . \ .)$$

so that each coefficient is a definite algebraic function of m, and we then have

$$X\phi(m, x) = F_0(m) \cdot x^m$$

the solution being completed by solving the equation $F_0(m) = 0$.

Differentiating as to m we have

$$X\frac{\partial}{\partial m}\phi(m, x) = F_0'(m) \cdot x^m + F_0(m) \cdot x^m \log x.$$

And thus if m is a repeated root of $F_0(m) = 0$

$$\phi \text{ and } \frac{\partial\phi}{\partial m}$$

are both solutions of (1).

If a particular solution of the equation $Xy = x^m$ is required it is furnished by $\phi(m, x)/F_0(m)$ unless $F_0(m)$ is zero, and when $F_0(m) = 0$ by

$$\frac{\partial\phi}{\partial m} \bigg/ F_0'(m)$$

and similarly in other cases.

It is also possible to meet the difficulty that arises when $F_0(m) = 0$ has two roots differing by a multiple of r, say μ and $\mu + br$, where b is a positive integer. Take $A_0 = m - \mu$ instead of 1, and $A_1, A_2 \ldots A_{b-1}$ are all algebraic fractions in m, each having $m - \mu$ as a factor in its numerator. $A_b, A_{b+1} \ldots$ will not in general have this factor, since it occurs in $F_0(m + br)$, the coefficient of A_b in the equation

$$A_b F_0(m + br) + A_{b-1} F_1(m + br - r) + \ldots = 0$$

by which A_b is given. We now have

$$X\phi(m, x) = F_0(m)(m - \mu)x^m$$

so that the factor $m - \mu$ is repeated on the right, and when $m = \mu$

$$\phi \text{ and } \frac{\partial\phi}{\partial m}$$

are both solutions of $Xy = 0$; ϕ differs only by a constant factor from $\phi(\mu + br, x)$, but $\partial\phi/\partial m$ is an independent solution.

In special cases $A_b, A_{b+1} \ldots$ may have the factor $m - \mu$, and then $\phi(\mu, x)$ vanishes identically, $\partial\phi/\partial\mu$ is a series of the ordinary type without logarithmic terms.

If there are three roots differing by multiples of r, let them be μ, $\mu + br$, $\mu + cr$, where b, c are both positive or zero. Then take $A_0 = (m - \mu)^2$, and the three solutions corresponding are

$$\phi, \quad \frac{\partial\phi}{\partial m}, \quad \frac{\partial^2\phi}{\partial m^2} \ (m = \mu).$$

The functions involved are such that the change of order of the differentiations can be easily justified.

Department of General Physics.

The following Papers were read:—

1. *A New Three-Colour Camera.* *By* Sir W. de W. Abney, *K.C.B., F.R.S.*

Some two years ago I brought out a new form of 'one-exposure' camera for three-colour work. The problem was to bring three images of the same object into focus and side by side on to one photographic plate, and also to make the angle of the included image of not less than 30°, and to impress all three images with one exposure. Of course if we have a wide camera and place three lenses equidistant from one another, and of exactly the same form, we obtain what we want, for we can expose them simultaneously. If we require a quarter plate image the lenses would have to be 3¼ inches apart, with the result that when we come to print from the three negatives and superpose the prints one over the other, as in the Sanger-Shepherd lantern-slide process, or in the ordinary typographical block process, we shall find that, owing to what may be called the stereoscopic effect produced by the distance apart of the lenses, the images will not fit. Two years ago I published the way by which the stereoscopic effect could be reduced to a minimum, and it became practically non-existent. Baldly it may be said that three simple lenses of very narrow aperture, about

3 inches in width, were placed side by side, touching one another. The rays from the two outside lenses were reflected 90° outwards, and when the necessary interval required between the pictures had been traversed the rays were again reflected 90°, and so all three images fell on one long plate. In the first camera I made, a second lens for the side images was placed in the path of the outer rays and came to a focus on the plate. They were so chosen that the images were of the same size as the central image. I may say that the results I got with this camera were exceedingly good, and all last winter I used it for my three-colour photographs. It had, however, the disadvantage that it was a camera with a fixed focus, since if the plate were moved back from the focus for parallel rays the central and side images no longer remained equal. I worked out a new optical arrangement, which had the advantage that all three images increased equally as the plate was moved from the focus for parallel rays. The problem that presented itself was this: to find combinations which gave images of equal focal length for parallel rays, and at the same time that the second principal points were at the same distance from the front lenses. If this were solved, as the three lenses were always at the same distance from any object, however near, a movement of the plate from the front lenses would still give images of the same size, no matter what distance the focus might be away.

As the problem also had to take into account the interposition of mirrors, it required many trial calculations to get the most suitable form of combinations which would keep the camera of reasonable dimensions. Eventually I fixed on three combinations which answered my purpose. The two outside combinations were of the same form, but the centre one was totally different. Beginning with the centre combination, the front lens was a convex of some 9-inch focus, and a second convex lens was placed about 4 inches away, of such focal length as to give a focus of 6 inches, the plate being placed 7·5 inches from the front lens. In the two side combinations the small front lens is concave, and the second lenses are placed about 1·5 inch away from the first lens. The first mirrors are not interfered with; they send the rays through the second lens and these fall on the second mirror. The images given by these three combinations are of the same size, each principal focal distance being the same. Further, the second principal points *are at the same distance from the front lenses*, and thus the problem was solved. I have brought the new camera with me. The first difficulty that I had was as to the material of which to make the mirrors. Having noted that a mirror made for Mr. V. Boys for some of his experiments was made of steel, and that after a lapse of many years it was practically unaltered in brightness and had no rust about it, I decided to make my mirrors of steel. They are readily worked to a flat sufficiently good for my purpose at any rate, and are supposed to reflect 60 per cent. of the incident light. I have not found it quite so much, 50 per cent. being nearer the mark. As there are two reflections I only got 25 per cent. of the light which strikes the first mirror. This, however, may be due to the fact that in order to render the steel surface impervious to damp I have coated all the mirrors with a very thin coating of celloidin varnish, which preserves it wonderfully (as it does that of silver, I may add), and does not alter the reflective power to any great extent; nor does it cause any distortion. As a second precaution against damp, chloride of calcium is kept in the camera, in the same form as used for preserving platinum paper.

It may be asked, What about distortion of the image and flatness of field and correction? The lenses are simple lenses and not achromatic. Correction for colour is unnecessary, since only a small portion of the spectrum is traversed on any one of the three screens. The flatness of field, Mr. Dennis Taylor, who has kindly given me every help in making the lenses for me, secured by dividing the second side-lenses into a pair and making them a compound lens. He also corrected the curvatures of the lenses, for the three different colours. There is a small quantity of distortion in each image, but the distortions are all equal. The camera itself, with its mirror and fittings, was carried out by Mr. Colebrook, of the Royal College of Science, under my own eye. I am greatly indebted to him for the care he has taken and the high-class work he has put into it.

I must add a few words as to the screens employed. They have been made in my laboratory with great care, and the light transmitted by them follows very closely the colour sensation curves after white has been abstracted from them.

I have with me a few negatives, which show the focus for parallel rays and also for portraits.

I do not know whether it is common knowledge that the best way of testing equal sizes of image is to take a transparency from one image and superpose it over the one to be tested. A want of equality of size is at once detected.

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2. *On the Measurement of Large Inductances containing Iron. By* Sir OLIVER LODGE, *F.R.S., and* BENJAMIN DAVIES.

We have had occasion lately to measure large inductances, up to and above 100 henries, with core consisting of subdivided iron in a nearly closed circuit, as used for certain telegraphic purposes with very weak currents. Since the inductance may vary rapidly with strength of current, it is necessary in any measurement to imitate the conditions of practice, and to determine the inductance as a function of current under those conditions. To this end we have designed a maximum-amplitude galvanometer, consisting of a well-damped coil moving *dead beat* in a strong magnetic field, and attached to a mirror so that the amplitude of its excursion can be observed. It can subsequently be calibrated by means of a steady current giving the same deflexion. The inductance to be measured is connected up in series with this galvanometer, and with a specially designed alternator of small power and known frequency $p/2\pi$, giving a sinuous or simply harmonic current. A switch allows the inductance to be suddenly replaced by a non-inductive adjustable resistance R'; and when under these conditions the same oscillation is produced in both cases, then the self-induction is equal to that equivalent resistance divided by the frequency constant; or $L = R'/p$. The strength of the current involved in this measurement is known by imitating the deflexion with a known steady current; and the main measurement consists simply in observing the deflexion caused by the sine-alternator, at a measured frequency, either with the inductance, or with the adjustable non-inductive resistance, indiscriminately. It is to be understood that the ohmic resistance of the wire wound on the self-induction is low. If not, a correction must be applied for that, which is easily done, since $\sqrt{(R^2 + p^2L^2)} = R'$.

The following empirical expression is found able to give the self-induction of a nearly closed magnetic circuit excited only by very weak currents, since for such currents it is found to be practically constant.

$$L = \frac{kn^a}{(G+g)^b}$$

where n is the number of turns, G the width of the air-gap in millimetres, and the other quantities are constants to be determined by experiment: though a will naturally be nearly 2. In an actual case of a nearly closed magnetic circuit the following values were found:—

$$a = 1{\cdot}99; \qquad b = 0{\cdot}47;$$
$$k = 18 \text{ henries}; \text{ and } g = 0{\cdot}1 \text{ millimetre}.$$

Results.

The result of this method of measurement applied to inductance coils of this type shows (1) that measurements based on a determination of the square root of mean square of current would serve fairly well for low magnetising forces; (2) that the self-inductance of such coils is for weak currents nearly independent of frequency, or say for all frequencies up to about 20 per second, when the magnetising force does not exceed 0·04 c.g.s.; (3) that the self-inductance of a nearly closed magnetic circuit is a definite and dependable function of the width of the air-gap for moderate currents and frequencies.

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3. *A Remarkable Feature in the Splash of a Rough Sphere.* *By* Professor A. M. Worthington, *C.B., F.R.S.*

The object of the communication was to exhibit and explain instantaneous photographs showing the remarkable change that occurs in the splash of a rough sphere falling vertically into a liquid, when the height of fall is increased beyond a certain critical value. (With a sphere of 1·5 cm. in diameter this critical height is reached below 140 cm. and above 70 cm. A further increase of height to 680 cm.—about $22\frac{1}{2}$ feet—makes no material difference.)

Below the critical height the splash is characterised by an upward jet thrown high into the air, the origin of which had been traced by the author many years ago. It is now found that when the critical height is passed the long cylindrical column of air which follows the sphere in its descent through the liquid is pierced by a central *downward* jet directed from above along the axis of the air-column. The photographs show that this downward jet is due to the permanent closing at an early stage of the mouth of the air-column by a film of the liquid, and to the subsequent reduction of the pressure of the confined air through the piston-like action of the sphere when its momentum is large enough.

(For details as to the method by which the photographs were taken and other information on the subject, reference may be made to the author's recently published 'Study of Splashes,' Longmans, 1908.)

4. *Analogy between Absorption from Solutions and Aqueous Condensation on Surfaces.* *By* Professor F. T. Trouton, *D.Sc., F.R.S.*

On introducing a solid, such as cellulose, into a solution, say, of an aniline dye, surface concentration or *adsorption* of the solute takes place in general, the amount of which is a function of the concentration and temperature.

For equilibrium with a solution of given concentration the higher the temperature the less the adsorption is found to be; but the adsorption may be preserved constant as the temperature is raised by increasing the concentration in a definite manner.

If curves are plotted, in terms of concentration and temperature as co-ordinates, along which the adsorption is constant (from the analogy with adsorption of water vapour by cotton these curves are called *isoneres*) it is found that all such curves, drawn for different amounts of adsorption, are similar to each other, and, further, they are found to be similar to the ordinary saturated curve for the solute in question.

This is analogous to the law of the isoneres for water vapour when we substitute osmotic pressure for concentration and the saturation curve of the solution for the boiling-point curve, that law being that at different temperatures the pressure ordinate of a given isonere is a constant fraction of the corresponding ordinate of the boiling-point curve.

Both relations were shown to follow from thermodynamic considerations.

5. *On the Effect of Pressure on the Boiling-point of Sulphur.* *By* Dr. J. A. Harker *and* F. P. Sexton.

Within the past few years it has been recognised that the platinum-resistance thermometer furnishes probably the most exact means we possess for temperature measurements over a very wide range. As is well known, the three fundamental fixed points, on which the scale of this instrument is based, are usually 0°, 100°, and the boiling-point of sulphur. The latter point is used in the determination of the characteristic constant of the particular kind of wire employed in the instrument. This constant is usually called the δ of the thermometer.[1] The determination of this δ is made by taking the resistance of the thermometer at the temperature of sulphur-vapour, boiling freely under the prevailing atmospheric pressure. Although the value of this temperature has been determined with accuracy by several different investigators for the normal pressure, its change with pressure has been always a matter of considerable uncertainty.

The authors have therefore made a redetermination of the effect of pressure on the boiling-point, carrying the range of the experiments well outside the usual atmospheric limits. Details will be given elsewhere in a later communication. The results of the experiments were found to be closely represented by the formula:—

$$T = T_s + \cdot 0904\,(p-760) - \cdot 0000519\,(p-760)^2$$

where T is the temperature of the vapour on the air-scale at the pressure p^{mm}, and T_s the 'normal' boiling-point.

The following table gives the value of the departure from normal boiling-point at various pressures to the nearest ·01° C.

Pressure	$T-T_s$ Degrees Cent.	Difference for 1 millimetre
700	−5·61	
		0·096
710	−4·65	
		0·095
720	−3·70	
		0·094
730	−2·76	
		0·093
740	−1·83	
		0·092
750	−0·91	
		0·091
760	−0·00	
		0·090
770	+0·90	
		0·089
780	+1·79	
		0·088
790	+2·66	
		0·087
800	+3·53	

It will be seen that the effect decreases somewhat rapidly with rise of pressure, and is much greater than the value usually employed—viz., 0·082 mm. per degree, deduced from Regnault's observations.

If, for example, the value of δ be calculated for a thermometer, whose true $\delta = 1{\cdot}500$ from observations made at 730 mm., the temperature of the vapour at this pressure being obtained by use of Regnault's values for the divergence from the normal temperature—the error in the δ thus obtained would be 0·018. This would lead to the scale of the instrument in use being in error by reading 0·36° C. high at 500° C. and 1·6° C. at 1000° C., quantities of importance for work of even moderate precision.

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[1] This is defined by the relation

$$d \equiv T - pt = \delta\left[\left(\frac{T}{100}\right)^{2} - \frac{T}{100}\right]$$

where d is the difference between the 'platinum temperature' pt, and the 'air temperature' T.

6. *On the Photometric Standard of the National Physical Laboratory. By* Dr. R. T. Glazebrook, *F.R.S.*

It was shown by Mr. Paterson in 1904 that the relation between the candle power of the 10-c.p. Vernon Harcourt Pentane Standard at the Laboratory and the humidity of the air is given by the equation, candle-power $= 10 + 0{\cdot}066(10 - \epsilon)$, where ϵ is the amount of moisture present measured in litres per cubic metre of air, so that the standard condition is when 10 litres of moisture are present and then the lamp has its nominal value 10 c.p.

In Mr. Paterson's experiments the quantity ϵ was measured in nearly all cases by an ordinary wet-and-dry bulb thermometer, and the observations reduced by the usual formula.

At the Reichsanstalt an Assmann ventilating hygrometer is employed for the purpose, and the International Commission on Photometry recommended at Zürich the use of some ventilating hygrometer.

This has led to a comparison of the two kinds of hygrometers in the still air of the photometer-room, with the result that it has been shown that the ordinary wet-and-dry bulb instrument over the range met with in practice gives results some 20 per cent. higher than the Assmann. The standard humidity then in the previous experiments when measured by the Assmann was 8 litres (not 10) per cubic metre, and Mr. Paterson's formula becomes, candle-power $= 10 + 0{\cdot}066(8 - \epsilon)$.

The paper discussed the question whether, since a change has to be made, it is desirable to retain the standard humidity at 10 litres measured by the Assmann, and in consequence change the light value at any given humidity of the National Physical Laboratory standard lamps by about 1·3 per cent., or retain the light value and change the standard humidity, and decided in favour of the latter alteration. In this the Gas referees concur.

The changes which are involved in consequence in the value of the ratio of the Pentane candle to the Hefner and to the Bougie decimal were considered, and it was shown that, adopting as the basis of comparison the results arrived at by the Commission at Zürich, and altering the standard value of the Pentane candle to 8 litres humidity, the Pentane candle and the Bougie decimal become practically equal, and each is equal to ten-ninths of the Hefner.

The practical conveniences of this were first pointed out to the author in a letter from the Bureau of Standards of America, and it is hoped that they will be thought sufficient to lead the International Gas Commission to consider the question of the change at their next session.

7. *An Improved Dry Daniell Pile. By* John Brown, *F.R.S.*

The author described a few improvements in this pile (which he had originally brought before the Section in South Africa), and gave notes of an experiment indicating its capability of maintaining a potential for several years, suitable for electrifying electrometer needles, &c. A copy of the pile had been made by Mr. John Finnegan, Belfast, two years ago, and found satisfactory and convenient.

Department of Cosmical Physics.

The following Papers were read:—

1. *Is our Climate Changing? By* Sir John W. Moore, *M.A., M.D.*

The author quoted remarkable instances of abnormal weather conditions, particularly in regard to temperature, which had been observed in recent years and in all seasons. Of these perhaps the most notable were the spell of cold weather which made memorable the Easter week of 1908, and the equally marked spell of belated or deferred summer heat which was experienced at the end of August and beginning of September 1906.

Such vagaries of the weather produce an extraordinary impression on men's minds, and on all sides we hear the remark, 'The seasons have changed. The severe winters of long ago, with their snow and ice, have disappeared; our summers are cool and rainy, our winters mild and windy; our autumns are warm and our springs are cold: in fact, there is a postponement of season, and it is progressive.'

The object of this paper was to test the accuracy of this popular opinion.

Among weather records of a past age reference was made to the Rev. William Merle's 'Consideraciones Temperiei pro 7 Annis' (1337-1344), from which it would appear that the weather was much the same at Oxford and at Driby, Lincolnshire, in the fourteenth century as it is at present.

The Greenwich records extend from the year 1774 to the present time. In a paper based on the observations taken at Greenwich from September 1811 to June 1856 inclusive, and read before the Royal Meteorological Society in December 1887, Mr. Henry S. Eaton concludes that 'there was no appreciable change in the mean annual temperature of the air at Greenwich in the period 1812 to 1855 inclusive.'

The late veteran meteorologist Dr. Alexander Buchan compared the mean temperature of the British Islands, as recorded in the twenty-four years 1857 to 1880, with the mean for a much more extended period, and found that at none of the British stations did the two values differ more than 0·3° F.

In 1770 Dr. Thomas Rutty published a work of 340 octavo pages, entitled 'A Chronological History of the Weather and the Seasons, and of the Prevailing Diseases in Dublin.' The results of forty years' observations are recorded in this volume. Rutty's remarks on the weather in Dublin in the early years of the eighteenth century would serve to describe accurately the weather of the twentieth century. This entertaining and instructive work teaches us that beyond doubt the seasons were as often erratic in the eighteenth century as we have found them to be in the nineteenth and twentieth centuries. Precisely the same story is told in 'A Diary of the Weather and the State of Vegetation at the Botanic Garden of the Dublin Society,' by John Underwood, A.L.S., head gardener and superintendent during the years 1802-1808 inclusive.

The remainder of the paper was devoted to an analysis of the observations made personally by the author from the year 1861 onwards to the present. His remarks were illustrated by four printed tables, setting forth respectively the monthly and yearly mean temperature of the air, as well as the lustrum averages, for the forty years 1866 to 1905 inclusive; the monthly and yearly rainfalls and the rain days and the lustrum averages for the same period, and the mean atmospheric pressure, with lustrum averages, in the forty years.

The average annual mean temperature of the period 1866 to 1905 inclusive in Dublin was 49°·7, the lustrum averages being 50°·1, 50°·2, 49°·3, 49°·4, 48°·6, 49°·4, 50°·8, and 50°.

The highest annual mean temperature was 51°·6 in 1898; the lowest was 47°·3 in 1879—the 'cold year.'

A careful study of this temperature table shows that, no matter what fluctuations may take place between individual months in successive years, or between individual years in successive lustrums, the temperature pendulum swings back to its original position at either side of the average.

The rainfall shows a variation from 45 per cent. in excess of the forty years' average—27·672 inches—to 40 per cent. in defect. The extreme excess occurred in 1872, when the rainfall was 35·566 inches; the extreme defect fell in 1887—Queen Victoria's Jubilee year—when the measurement was only 16·601 inches.

The average annual number of rain days in Dublin is 196. In 1870 the number fell to 145; in 1872 it rose to 238.

Atmospheric pressure is on the average of the forty years 29·920 inches in Dublin. The mean annual pressure varied from 29·731 inches in 1872 to 30·015 inches in 1887. The extreme readings of the barometer were 31·020 inches at 10 A.M. of January 9, 1896, and 27·758 inches at 2.30 P.M. of December 8, 1886—a range of 3·262 inches, or rather more than $3\frac{1}{4}$ inches.

In conclusion the author submitted that the facts put forward in his paper prove that, within the past six centuries at all events, no appreciable change has taken place in the climate of the British Isles. There is not a scintilla of evidence to show that any such change has taken place in the past or is likely to take place in the future.

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2. *A Comparison of the Changes in the Temperature of the Waters of the North Atlantic, and in the Strength of the Trade Winds. By* Commander M. W. C. HEPWORTH, *C.B., R.N.R.*

In order to confine that portion of the inquiry which relates to the trade winds within manageable limits, two representative areas were selected for examination. One of these lies well within the region of the north-east trade wind, and covers an area of 1,000,000 square miles; the other is in the heart of the south-east trade wind, and covers an area of 1,380,000 square miles. For the former homogeneous averages for a period of five years only are available; but for the latter the results of four hourly observations, extending over a period of forty-five years, have been utilised for estimating normal conditions. Judged by the five years' averages, the north-east trade is strongest in April (13·5 statute miles per hour); relatively strong in February (13 miles); in March (12·6 miles); and in May (12·4 miles). It then rapidly declines in strength until August, when its velocity is only 8·2 miles per hour. It is lightest (7·4 miles) in September. From October its strength increases until February. According to the average results obtained for the forty-five years' period mentioned, the south-east trade is strongest (15·5 miles per hour) in February; relatively strong (15 miles) in April and November; also in March and December (14·9 miles). It is at about its average strength for the year (14·7 miles) in January, August, and October. In May it is lightest (13·7 miles), and from that month gradually increases, and is again at its average strength for the year in August. It declines to 14·5 miles in September.

To represent the North Atlantic in a comparison of the changes taking place in the surface temperature of that ocean two zones were selected—the one lying between Florida Strait and Valencia, and the other between that Strait and Cape Race. Average results, based on observations extending over a long series of years, showed that the temperature of the surface water is lower in February, March, and April than during any other period of the year, and is lowest in March. It is relatively low, as compared with any other months than the above, in January, May, and December, and of these months January has the lowest mean surface temperature, and May the highest. The surface temperature is relatively high in June, October, and November; highest as regards those months in October, lowest in November. It is higher in July, August, and September than during any other period of the year; highest of all in August, not quite so high in July as in September, in the Florida Strait to Valencia zone; but in the Florida Strait to Cape Race zone the mean is found to be the same in these two months. A comparison between results of Atlantic trade-wind velocity in each of the years 1902–7 and those of North Atlantic surface temperatures for the same period leads to the belief that a relation may be traced between departures from the mean in the velocities of the trades in any one year and deviations from normal in the average distribution of surface temperature in the North Atlantic in the year following. Further, there is some evidence to prove that departures from the average strength of the two trades during a series of months, and at times during even so short a period as a month, are roughly reflected in deviations from normal in the average distribution of surface temperature in the North Atlantic in the corresponding series of months, or month, as the case may be, of the succeeding year, notwithstanding the many causes affecting the temperature of the surface water, which must tend to mask the appearance of any such connection.

A large number of tables and diagrams accompanied the paper.

3. *Temperature Conditions in Scottish Lochs.* *By* E. M. Wedderburn, *F.R.S.E.*

Very complete observations have been made in connection with the Scottish Lake Survey in Loch Ness, which is a lake of the Tropical class, with a length of 22½ miles and a maximum depth of 750 feet. Numerous observations have also been made in Loch Garry (Inverness-shire), which is a lake of the Temperate class, from February to July 1908. The main basin of this lake has a length of about 4 miles and a maximum depth of about 220 feet.

These observations indicate that in winter, at which time the lakes are of nearly uniform temperature throughout, the effect of winds blowing along the surface of the lake is to produce a circulation of the whole of the water in the lake; and further, that in summer, when the water in the lake has had a considerable accession of heat, mainly by isolation and conduction, the effect of winds blowing along the surface is to produce a discontinuity in the temperature gradient of the lake at a depth dependent on the particular circumstances of each case.

An experimental investigation in which a long glass trough was used to represent the basin of a lake, and difference in density of the liquid was used to imitate difference of temperature, indicates that the discontinuity is produced by the return current, induced in the lake by the wind-produced surface current becoming localised and taking place at a relatively small depth when the increase of temperature at the surface has produced considerable differences in temperature in the lake.

Whenever the discontinuity is pronounced the layer of water above it behaves independently of the lower layer. The surface layer shows changes which can be directly traced to the action of the wind driving the warm water to one end of the lake. The lower layer shows great variations of temperature, and it has been satisfactorily demonstrated that these variations in temperature are due to what is called a temperature seiche in the lower liquid, with period dependent, *inter alia*, on the depth of the discontinuity and the difference in density between the upper and lower layers. The amplitude of this temperature seiche in Loch Ness was at times from 150 to 200 feet, and the period was about three days. In Loch Garry the period of oscillation was about twelve hours.

Observations were made in Loch Garry and Loch Ness in 1908 with Ekman's propeller current meter.

Owing to the experimental difficulties encountered, and the danger of making lengthy observations in high winds, the observations have not been so complete as was hoped for, and must be looked upon as preliminary. They show, however, that early spring currents are appreciable at very great depths, and that later in the year the currents are chiefly felt near the surface.

The author has been criticised for generalising from Scottish Lochs, which are narrow and situated in glens in which the wind can only blow with any force in one of two directions, to broad and open lakes. It seems unlikely, however, that the phenomena observed in these lakes do not have their counterpart in all lakes, except in those which are very shallow and are kept of uniform temperature from top to bottom by the action of winds. In Continental lakes there are no observations known to the author which are sufficient to detect oscillations similar to those noticed in Scottish lochs.

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4. *The Constants of the Lunar Libration.* *By* F. J. M. Stratton.

A reinvestigation of the heliometer observations of Mösting, A., made by Schlüter at Königsberg in the years 1841–43, has been undertaken in the hope of reconciling the conflicting sets of constants for the lunar libration given by Drs. Franz and Hayn.

The expense of the work of checking the computations has been borne in part by a grant from the Royal Society.

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5. *Investigations on the Electrical State of the Upper Atmosphere.* *By* W. Makower, Margaret White, *and* E. Marsden.

The investigations made during July and August 1908 is chiefly concerned with the measurement of the electrical currents flowing from a kite down the wire by which it is attached to the winding machine. In the first experiments different lengths of wire were let out with the kite, detached from the winding machine, and the free end of the wire attached to an ebonite insulator fixed to the ground. The kite was then connected to earth through a sensitive dead-beat galvanometer and the current measured. In these experiments the currents at considerable heights were so large that it was found necessary to reduce the sensitiveness of the galvanometer by shunting. The plan was therefore adopted in later experiments of using as a shunt a portion of the kite wire when attached to the drum of the winding machine, which was earthed, and thus making use of the usual daily flights taking place at the Glossop observatory. The mean currents obtained are given in the accompanying table:—

Height of Kite above Ground	Current in Amperes
2,000 feet	5×10^{-5}
4,000 „	13×10^{-5}
6,000 „	23×10^{-5}

The current at any fixed height varied considerably from day to day. There seemed, however, to be a fairly close connection between the current and wind velocity, the currents being great when the wind was high. A few experiments have been made on the potential of the air at different heights, but no very reliable results have yet been obtained, on account of the difficulty of satisfactorily insulating for the high potentials to be measured.

TUESDAY, SEPTEMBER 8.

Department of Mathematics.

The following Papers were read:—

1. *Applications of Quaternions to Problems in Physical Optics.* *By* Professor A. W. Conway.

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2. *On a Generalisation of the Question in Probabilities known as 'Le Scrutin de Ballotage.'* *By* Major P. A. MacMahon, *F.R.S.*

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3. *On Conformal Transformations of a Space of Four Dimensions and their Application to Geometrical Optics.* *By* H. Bateman.

The study of the conformal transformations of a space of four dimensions is simplified by the introduction of the six homogeneous coordinates

$$l = x + iy \qquad m = z + iw \qquad n = x^2 + y^2 + z^2 + w^2$$

$$\lambda = x - iy \qquad \mu = z - iw \qquad \nu = -1$$

connected by the identical relation

$$l\lambda + m\mu + n\nu = 0.$$

A function $V=F(x, y, z, w)$ when expressed as a homogeneous function of degree zero in $(l, m, n, \lambda, \mu, \nu)$ will be a solution of

$$\left(\frac{\partial F}{\partial x}\right)^2 + \left(\frac{\partial F}{\partial y}\right)^2 + \left(\frac{\partial F}{\partial z}\right)^2 + \left(\frac{\partial F}{\partial w}\right)^2 = 0$$

if

$$\frac{\partial V}{\partial l}\frac{\partial V}{\partial \lambda} + \frac{\partial V}{\partial m}\frac{\partial V}{\partial \mu} + \frac{\partial V}{\partial n}\frac{\partial V}{\partial \nu} = 0$$

when expressed as a homogeneous function of degree -1 in $(l, m, n, \lambda, \mu, \nu)$ it will be a solution of

$$\frac{\partial^2 F}{\partial x^2} + \frac{\partial^2 F}{\partial y^2} + \frac{\partial^2 F}{\partial z^2} + \frac{\partial^2 F}{\partial w^2} = 0$$

if

$$\frac{\partial^2 V}{\partial l \partial \lambda} + \frac{\partial^2 V}{\partial m \partial \mu} + \frac{\partial^2 V}{\partial n \partial \nu} = 0$$

A particular solution of the last equation, which is a homogeneous function of degree -1, is given by

$$V = l^{-a}\lambda^{-a'}m^{-\beta}\mu^{-\beta'}n^{-\gamma}\nu^{-\gamma'}\ P\begin{pmatrix} a & b & c & \\ a & \beta & \gamma & \theta \\ a' & \beta' & \gamma' & \end{pmatrix}$$

where P is Riemann's general hypergeometric function and

$$l\lambda=(b-c)(\theta-a), \qquad m\mu=(c-a)(\theta-b), \qquad n\nu=(a-b)(\theta-c)$$

$$a+a'+\beta+\beta'+\gamma+\gamma'=1.$$

The group of conformal transformations is derived from the group of automorphic linear transformations of the coordinates $(l, m, n, \lambda, \mu, \nu)$ in which the expression

$$l\lambda+m\mu+n\nu$$

is left unaltered in form.

By putting $w=ivt$, where v is the velocity of light, we may obtain a number of transformations which can be applied to optical problems. Of these we shall mention two:—

$$X = \frac{x}{r^2-v^2t^2}, \quad Y = \frac{y}{r^2-v^2t^2}, \quad Z = \frac{z}{r^2-v^2t^2}, \quad T = \frac{t}{r^2-v^2t^2}$$

and

$$X = \frac{x}{z-vt}, \quad Y = \frac{y}{z-vt}, \quad Z = \frac{1+v^2t^2-r^2}{2(z-vt)}, \quad vT = \frac{1-v^2t^2+r^2}{2(z-vt)}.$$

In either case if $F(X, Y, Z, T)$ is a solution of

$$\frac{\partial^2 F}{\partial X^2} + \frac{\partial^2 F}{\partial Y^2} + \frac{\partial^2 F}{\partial Z^2} = \frac{1}{v^2}\frac{\partial^2 F}{\partial T^2}$$

so that when $F=0$ is solved for T, the function T is the characteristic function of a series of parallel wave surfaces, the transformation gives us an expression for F in terms of (x, y, z, t), which is also such that if the equation $F=0$ be solved for t, then t is the characteristic function for a second system of parallel surfaces. In the case of the first transformation the surface $t=0$ is the inverse of the corresponding surface $T=0$. This transformation may be studied further by supposing a point (x, y, z) to start at a point (ξ, η, ζ) on a surface f, and to move with uniform velocity v along a straight line whose direction cosines are (l, m, n), so that its coordinates at time t are given by

$$x=\xi+lvt, \qquad y=\eta+mvt, \qquad z=\zeta+nvt.$$

The corresponding point (X, Y, Z) can be shown to start at the point $(\Xi, \mathrm{H}, \mathrm{Z})$, which is the inverse of (ξ, η, ζ), and to travel with velocity v along a straight line whose direction cosines are (L, M, N), so that at time

$$T = \frac{t}{r^2 - v^2t^2}$$

$$X = \Xi + LvT, \qquad Y = \mathrm{H} + MvT, \qquad Z = \mathrm{Z} + NvT,$$

where

$$L = l - \frac{2\xi}{\rho^2}(l\xi + m\eta + n\zeta), \text{ \&c.} \quad (\rho^2 = \xi^2 + \eta^2 + \zeta^2)$$

These formulæ establish a correspondence between the rays which are incident at points of a surface f and the rays which are incident at points of the inverse surface F. If (p, q, r) are the direction cosines of the normal at (ξ, η, ζ) to the surface f, the corresponding quantities (P, Q, R) are the direction cosines of the normal to the inverse surface F. If (l, m, n) (l', m', n') are the direction cosines of a ray before and after refraction at the surface f, the corresponding quantities (L, M, N) (L′, M′, N′) are the direction cosines of a ray before and after refraction at the inverse surface F, the refractive index of a portion of space being the same as that into which it is transformed by inversion.

A ray through the origin is seen to correspond to a ray passing through the origin but travelling in the opposite direction. A pencil of rays passing through any given point in space is seen to correspond to a system of rays which meet the line joining the given point to the origin.

It is evident from these considerations that the method can be applied successfully to the solution of problems in geometrical optics. A geometrical construction for the point (X, Y, Z, T) is obtained by describing a sphere of radius vt round the point (x, y, z). The inverse sphere is of radius vT, and its centre is at the point (X Y Z).

4. *On the Extension of Optical Ideas to General Electromagnetic Fields. By* Professor E. T. Whittaker, *Sc.D., F.R.S.*

It was shown in this paper that the resolution of a beam of light into two components polarised in planes at right angles to each other leads to an expression of the state of the luminiferous ether in terms of two potential functions, one of which corresponds to each of the polarised beams. It was then shown that the state of the ether can be expressed in terms of these two potential functions, not only in the case in which the disturbance consists simply of luminous or electromagnetic waves, but also in the more complicated cases when electrostatic charges and voltaic currents are present in the field. It thus appears that the ether is a medium with two essential qualities, which are both scalar (like the pressure and temperature of a gas) and the various vectors in terms of which the electromagnetic field is usually specified (*e.g.*, the electric force and magnetic induction) are merely derived from the variation of these two qualities in space and time.

5. *Distribution of Electricity on a Moving Sphere. By* Professor A. W. Conway.

6. *The Theory of Solids moving in an Incompressible Fluid. By* Professor F. Purser, *F.T.C.D.*

Some years ago a paper was published by my brother, the late Professor John Purser, of Queen's College, Belfast, in the 'Philosophical Magazine' in which he demonstrated the applicability of the generalised dynamical equations of Lagrange to the case of solids moving in an incompressible fluid.

As I believe the method adopted in this to constitute the simplest and most satisfactory solution of the problem, I would endeavour in the present paper to present it in a modified form, which may perhaps more clearly bring out its scope and spirit. The difficulty to be overcome arises, as is well known, from the fact that though, assuming a velocity potential, the velocities of any point x, y, z of the fluid are determined in terms of the $q'_1, q'_2 \ldots$ representing the motions of the solids, or assuming a displacement potential, the displacements of x, y, z are determined in terms of $dq_1, dq_2 \ldots$ it is not possible, as is required for the applicability of the Lagrangian equations, to express the coordinates x, y, z themselves in terms of $q_1, q_2 \ldots$

Now, although this cannot be done, we may, starting from a given configuration of the solids supposed at rest, and connecting q_1, q_2 as functions of a single variable, express in terms of this variable the position of a given point x, y, z. We may, in fact, conceive the following process: Sudden connected velocities $q_1', q_2' \ldots$ are imparted to the solids, determining corresponding velocities of x, y, z. After an indefinitely small time the solids are stopped, and therefore x, y, z is also brought to rest. The process is then repeated with new connected velocities $q'_1 \ldots$ producing a new velocity of x, y, z again reduced to rest. In this way, by what we may term a continuous system of jerks, x, y, z is continuously displaced by

$$\frac{dx}{dq_1} dq_1 \cdot \frac{dx}{dq_2} dq_2 \ldots$$

$$\frac{dy}{dq_1} dq_1 \quad \ldots$$

$$\frac{dz}{dq_1} dq_1 \quad \ldots$$

It will be observed (1) that in this notation

$$\frac{d}{dq_2} \frac{dx}{dq_1}$$

is not identical with

$$\frac{d}{dq_1} \frac{dx}{dq_2}$$

(2) that in forming

$$\frac{d}{dq_r} \frac{dx}{dq_s}$$

we must have regard to the generalised coordinates q, not only as they occur in q_s, but as they arise from the variations of x, y, z, i.e., we follow the particle. Consider now the virtual moment which in general gives rise to the Lagrangian equations, viz. :—

$$\sum \left(\frac{d^2x}{dt^2} dx + \frac{d^2y}{dt^2} dy + \frac{d^2z}{dt_2} dz \right) dm.$$

For the solids x, y, z being now functions of q_1, q_2, this yields the Lagrangian equation. For the third we throw the virtual moment into the form $\Sigma\, Q_m dq_m$, where Q_m

$$= \sum dm \left(\frac{d^2x}{dt^2} \frac{dx}{dq_m} + \frac{d^2y}{dt^2} \frac{dy}{dq_m} + \frac{d^2z}{dt^2} \frac{dz}{dq_m} \right)$$

$$\text{Now } \frac{d^2x}{dt^2} \frac{dx}{dq_m} = \frac{d}{dt} \cdot \frac{dx}{dt} \frac{dx}{dq_m} - \frac{dx}{dt} \frac{d}{dt} \frac{dx}{dq_m}$$

with analogues y, z.

The former term, since $\frac{dx}{dq_m} = \frac{d}{dq'_m} \frac{dx}{dt}$, gives rise to $\frac{d}{dt} \frac{dT}{dq_m}$

The second term may be written

$$-\frac{dx}{dt}\cdot\frac{d}{dq_m}\frac{dx}{dt}+\frac{dx}{dt}\left(\frac{d}{dq_m}\frac{dx}{dt}-\frac{d}{dt}\frac{dx}{dq_m}\right)$$

The two first terms give then the Lagrangian equations

$$\frac{d}{dt}\frac{dT}{dq_m}-\frac{dT}{dq_m}$$

It remains to consider the integral corresponding to

$$\frac{dx}{dt}\left(\frac{d}{dq_m}\frac{dx}{dt}-\frac{d}{dt}\frac{dx}{dq_m}\right)$$

with analogues in y, z.

It will be convenient at this stage to suppose the variables two in number q , q_2, the spirit of the proof being general. We have then

$$\frac{d}{dq_1}\frac{dx}{dt}=\frac{d}{dq_1}\left(q'_1\frac{dx}{dq_1}+q'_2\frac{dx}{dq_2}\right)=q'_1\frac{d}{dq_1}\frac{dx}{dq_1}+q'_2\frac{d}{dq_1}\frac{dx}{dq_2}$$

$$\frac{d}{dt}\frac{dx}{dq_1}=q'_1\frac{d}{dq_1}\frac{dx}{dq_1}+q'_2\frac{d}{dq_2}\frac{dx}{dq_1}$$

the corresponding terms thus becoming

$$\frac{dx}{dt}q'_2\left(\frac{d}{dq_1}\frac{dx}{dq_2}-\frac{d}{dq_2}\frac{dx}{dq_1}\right)$$

Similarly

$$\frac{dx}{dt}\left(\frac{d}{dq_2}\frac{dx}{dt}-\frac{d}{dt}\frac{dx}{dq_1}\right)=+\frac{dx}{dt}q'_1\left(\frac{d}{dq_2}\frac{dx}{dq_1}-\frac{d}{dq_1}\frac{dx}{dq_2}\right)$$

Let now

$$\frac{d}{dq_2}\frac{dx}{dq_1}-\frac{d}{dq_1}\frac{dx}{dq_2}=X$$

$$\frac{d}{dq_2}\frac{dy}{dq_1}-\frac{d}{dq_1}\frac{dy}{dq_2}=Y$$

$$\frac{d}{dq_2}\frac{dz}{dq_1}-\frac{d}{dq_1}\frac{dz}{dq_2}=Z$$

Then we have evidently only to show that

$$\iiint\left(\frac{dx}{dt}X+\frac{dy}{dt}Y+\frac{dz}{dt}Z\right)=0$$

Now consider the total increment Δx, Δy, $\Delta (z)$ arising from integrating

$$\frac{dx}{dq_1}dq_1+\frac{dx}{dq_2}dq$$

along a closed course of q_1, q_2. The result by a well known theorem of Stokes gives

$$\Delta x=\iint X dq_1\,dq_2$$

$$\Delta y=\iint Y dq_1\,dq_2$$

$$\Delta z=\iint Z dq_1\,dq_2$$

If we suppose the circuit of q_1, q_2 indefinitely small these become

$$X dq_1\,dq_2,\ Y dq_1\,dq_2\ Z dq_1\,dq_2$$

or representing q_1 q_2 by coordinates of a point $Xd\mathrm{S}$, $Yd\mathrm{S}$, $Zd\mathrm{S}$, $d\mathrm{S}$ being the area of elementary closed circuit. Now Δx, Δy, Δz represents an indefinitely small displacement:—

$$\therefore \frac{d\Delta x}{dx} + \frac{d\Delta y}{dy} + \frac{d\Delta z}{dz} = 0.$$

Again, by the nature of the process considered any point in contact with a solid remains in contact with it. When then q_1, q_2 have returned to their original values the displacement represented by Δx, Δy, Δz is tangential to the solid. Now

$$\frac{dx}{dt} = \frac{d\phi}{dx}, \quad \frac{dy}{dt} = \frac{d\phi}{dy}, \quad \frac{dz}{dt} = \frac{d\phi}{dz} \quad \therefore \iiint \left(\frac{dx}{dt} \mathrm{X} \ . \ . \ . \right) dx\, dy\, dz$$

$$= \iint \phi\, (\mathrm{X}\, dy\, dz + \mathrm{Y}\, dz\, dx + \mathrm{Z}\, dx\, dy)$$

$$- \iiint \phi \left(\frac{d\mathrm{X}}{dx} + \frac{d\mathrm{Y}}{dy} + \frac{d\mathrm{Z}}{dz} \right) dx\, dy\, dz$$

Both these terms vanish from considerations above. Hence our theorem is established.

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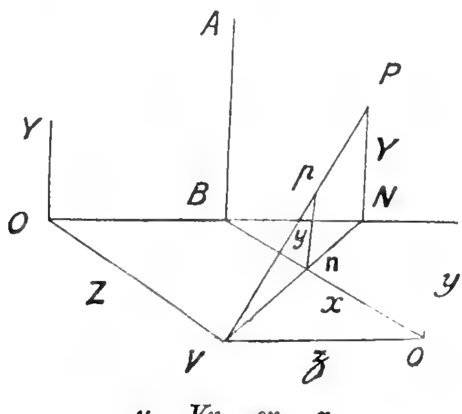
7. *On the Analysis of Projection. By* Professor R. W. Genese, *M.A.*

The importance of projection in the study of the points at infinity of a graph makes a simpler treatment than that which appears in the usual texts desirable.

p in the plane ABoy is projected from V into P in the plane ABOY; VoBO is a plane perpendicular to AB; VOY, Voy planes parallel to ABo, ABO respectively, so that oy, OY are the so-called vanishing lines of the planes.

ON = X, NP = Y being the coordinates of P, the plane VPN is parallel to AB and meets the plane ABo in np parallel to AB or oy. Taking $on = x$, $np = y$ we have



$$\frac{y}{\mathrm{Y}} = \frac{\mathrm{V}n}{\mathrm{VN}} = \frac{on}{o\mathrm{B}} = \frac{x}{\mathrm{Z}}.$$

and also $$= \frac{\mathrm{OB}}{\mathrm{ON}} = \frac{z}{\mathrm{X}}.$$

where Z, z are the shortest distances of V from each plane measured parallel to the other plane.

Now we may agree to take Z, z as different units of length for the two planes, and the equations of transformation become

$$\frac{y}{\mathrm{Y}} \ \frac{x}{\mathrm{I}} = \frac{1}{\mathrm{X}}.$$

Hence the following simple rule: *Make the equation to a curve in the* x, y *plane homogeneous by the usual* z; *interchange* z *and* x, *and we obtain the equation to the projection.*

Thus the cubical parabola $y^3 = x = xz^2$ becomes $Y^3 = ZX^2 = X^3$, the semi-cubical parabola. The same curve in a different position, viz., $y = x^3$, or $yz^2 = x^3$, projects into $YX^2 = 1$.

In practice it will not be necessary to retain the two sets of letters; we may say that

$$y = e^x = ze^{\frac{x}{z}} \text{ projects into } y = xe^{\frac{1}{x}}$$

$$y = \log x = z \log \frac{x}{z} \text{ projects into } y = x \log \frac{1}{x}$$

$$y = \cos hx = z \cos h\frac{x}{z} \text{ projects into } y = x \cos h\frac{1}{x}.$$

$$y = a_0 + a_1x + a_2x^2 + a_3x^3 + \ \&c.$$

$$= a_0z + a_1x + a_2\frac{x^2}{z} + a_3\frac{x^3}{z^2} + \quad . \ . \ .$$

projects into

$$y = a_0x + a_1 + a_2\frac{1}{x} + a_3\frac{1}{x^2} + \quad . \ . \ .$$

Or, generalising,

$$y = f(x) \text{ projects into } y = xf\left(\frac{1}{x}\right).$$

From the transformation

$$y = \frac{Y}{X}, x = \frac{1}{X}$$

we obtain

$$\frac{dy}{dx} = Y - X\frac{dY}{dX}$$

$$y - x\frac{dy}{dx} = \frac{dY}{dX}$$

Hence the solutions of

$$y - x\frac{dy}{dx} = f\left(\frac{dy}{dx}\right)$$

project into those of

$$Y - X\frac{dY}{dX} = f^{-1}\left(\frac{dY}{dX}\right)$$

Also

$$\frac{d^2y}{dx^2} = X^3\frac{d^2Y}{dX^2}$$

$$= \frac{Y^3}{y^3}\frac{d^2Y}{dX^2}$$

therefore

$$y^3\frac{d^2y}{dx^2} = Y^3\frac{d^2Y}{dX^2}$$

If the constants z, Z be retained, the relation is

$$\frac{y^3}{z^2}\frac{d^2y}{dx^2} = \frac{Y^3}{Z^2}\frac{d^2Y}{dX^2},$$

of zero dimensions, as might be expected.

Department of General Physics.

The following Papers were read:—

1 *A Suggestion with regard to the Meaning of Valency.* *By* H. Bateman.

Starting with the hypothesis that an atom contains a large number of charged particles some evidence can be brought forward in support of the view that changes can take place in the configuration or state of motion of the particles which do not involve a corresponding change in the spectrum.

Let a sphere be described round each particle as centre, and let the radii of the spheres be chosen so that there are a number of contacts between the different spheres. We shall suppose that a node of the vibrations exists at a point of contact when two spheres touch externally, provided the particles at their centres carry similar charges, and when two spheres touch internally, provided the particles carry opposite charges.

Now a number of spheres, the members of which have a certain number of contacts with one another, is transformed into another system with the same number of contacts by any conformal transformation of space.

Diagram I.—Expulsion of a particle or group of particles from an atom.

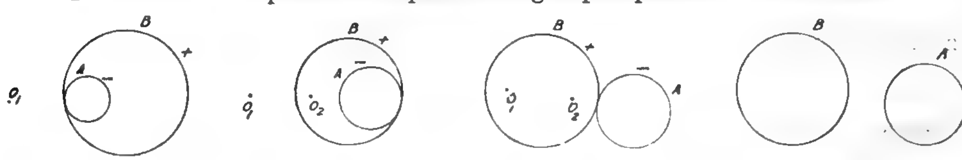


Fig. 1. Fig. 2. Fig. 3. Fig. 4.

Diagram II.—Rayless change (the shaded region may be occupied by any number of spheres).

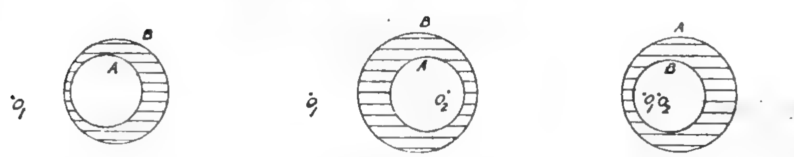


Fig. 1. Fig. 2. Fig. 3.

An infinitesimal transformation of this type may be built up from two inversions where the spheres of inversion are very nearly coincident. Four parameters are required for the specification of each sphere, so that the total number of variables in the transformation is eight. The correspondence between this number and the maximum valency of an atom suggests that there may be a group of conformal transformations associated with an atom involving arbitrary parameters in number equal to the valency of the atom. A succession of infinitesimal transformations would correspond to a motion of the charged particles within the atom, so that on this view the valency would represent the number of degrees of freedom for a departure from a given configuration or state of motion of the charged particles contained in the atom.

When two atoms combine each can be supposed to lose a number of degrees of freedom, a 'bond' of the chemist corresponding to a pair of equations involving the valency coordinates, and one or more equations involving only the positional coordinates.

To show that the periods of vibration of the atom are unchanged by a conformal transformation we may fix our attention on a particular sphere S which always passes through a node N in the course of the vibrations. The corresponding sphere S′ will always pass through the corresponding node N′, and it is clear that whenever S returns to its initial position S′ will do so also.

A possible description of a radio-active change may be based on the fact that the type of contact of two spheres alters when the centre of inversion lies within one sphere.

In the diagrams O_1, O_2 are the centres of inversion; the second figure in each case represents the effect of the first inversion, the third figure the effect of the second inversion. In diagram I. fig. 3. the point of contact is no longer a node, since the spheres touch externally and are associated with oppositely charged particles; consequently the spheres are not required to remain in contact and can separate.

(NOTE.—The idea of attaching a physical meaning to the point of contact of the spheres was not given in the original manuscript presented to the Association; it was introduced later during the formation of an abstract.)

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2. *Secondary Radiation.* *By* Professor J. A. McCLELLAND.

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3. *The Scintillations of Zinc Sulphide.* *By* Professor E. RUTHERFORD, *F.R.S.*

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4. *A Determination of the Rate of Evolution of Heat by Pitchblende.* *By* HORACE H. POOLE.

A spherical vacuum jacketed vessel with a narrow neck is filled with powdered and carefully dried pitchblende. The neck is filled with cottonwool and rendered watertight with sheet rubber, and the whole is buried in ice. The difference of temperature between the layer of pitchblende in contact with the bottom of the vessel and the ice is measured by a sensitive thermo-couple. After about a fortnight this temperature becomes steady, when the heat leakage across the walls of the vessel is equal to the heat generated by the pitchblende. This leakage depends solely on the vessel and on the difference of temperature between inner and outer walls, which is measured by the thermo-couple. The thermal conductance of the vessel is found by substituting water for the pitchblende and determining its rate of cooling. Hence the heat leakage is known, and, knowing the amount of pitchblende present, the heat evolution per gram is found.

The thermo-couple is calibrated by placing one junction in finely broken ice and the other in a mixture of broken ice and water, which can be subjected to a known pressure. The deflection caused by the resulting small change of temperature is noted, and hence sensitiveness of couple is found.

Using 560·7 grs. of pitchblende in an atmosphere of nitrogen, the temperature finally steadied at 0°·0092 C. As the thermal conductance of vessel is 5·8 calories per hour per degree difference of temperature between inside and outside, this corresponds to a heat leakage of 0·053 calorie per hour. Hence heat evolution per gram of pitchblende is 0·000094 calorie per hour. This is about twice the quantity estimated from the known amount of radium present.

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5. *The Grating Spectrum of Radium Emanation.* *By* T. ROYDS, *M.Sc.*

Using a concave grating of 1 metre radius, intended for faint spectra, it has been possible to obtain more accurate measurements of the wave-lengths of the more intense lines in the emanation spectrum. The grating has a width of 3·5 inches, containing 15,000 lines to the inch. The dispersion in the first order amounts to 16·8 A.U. per millimetre.

A small vacuum tube, made from capillary tubing and fitted with platinum electrodes, was filled to a pressure of about 1 mm. of mercury, with radium emanation purified with Rutherford's apparatus and method.[1] A quartz condensing lens was employed, and the iron arc used to give a comparison spectrum. Three photographs were obtained, two being of the end-on discharge seen through a quartz window.

About thirty-five of the more intense lines previously obtained by Rutherford and Royds[2] with a glass prism can be seen on the photographs, together with four additional lines further in the ultra-violet. The spectrum presents the same characteristics as those previously obtained, and the measurements are in good agreement. The error in the wave-lengths of the grating photographs is not more than about 0·1 A.U.

6. *Photographs of Arc Spectra of Metals under Pressure.* *By* Dr. W. G. Duffield.

7. *Secondary Effects in the Echelon Spectroscope.* *By* H. Stansfield, *B.Sc.*

Further experiments made with the echelon spectroscope described at the Leicester meeting of the Association have shown that some of the variations in the spectra have their origin in the instrument. For example, a dark line that is often observed in the bright central band of the given mercury line spectrum, and has been supposed to be an absorption line, can be moved across from one side of the band to the other by a slight rotation of the echelon about a vertical axis.

These effects are found to be due to the superposition on the primary spectrum of secondary light that has been twice reflected in the echelon.

If a bright line spectrum is examined with the echelon in the ordinary position, the secondary effects are not conspicuous, as the secondary lines are parallel to the spectrum lines and can only be formed on a fairly broad band such as the central band of the green mercury line; but on rotating the echelon about a vertical axis the secondary lines will be seen crossing the broad bands in the spectrum as they move in the same direction as the spectrum lines and move much faster.

When the echelon is raised at one end the secondary lines become conspicuous; they are more inclined than the spectrum lines, in the same direction, and give them a screw-like appearance.

With the echelon in this position it is not difficult by means of screens to obtain the secondary spectrum free from primary. It is also possible to obtain the primary spectrum so free from secondary light that the spectrum lines lose their screw-like appearance.

The secondary action of the echelon in forming a spectrum by internal reflection is similar to that of a Fabry and Perot spectroscope. This action alone would throw the secondary light into a ring spectrum, but as it emerges from the step faces of the echelon the light also undergoes the ordinary echelon treatment and so it is confined to the points of intersection of lines representing the same wave length in the ring spectrum and the echelon spectrum. The secondary lines observed in the spectrum resulting from the superposition of the primary and secondary spectra are the loci of these points of intersection.

The distance apart of the secondary lines, their motion when the echelon is rotated, and their inclination when one end of the echelon is raised have been calculated in accordance with this theory, and the results agree well with the observations.

The use of the secondary point spectrum extends the resolving power of the instrument and gives a method of verifying the measurements made in the usual way.

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[1] Rutherford, 'Experiments with Radium Emanation,' *Phil. Mag.*, August 1908.
[2] Rutherford and Royds, 'Spectrum of Radium Emanations,' *ibid.*

8. *Further Experiments on the Constitution of the Electric Spark. By* T. Royds, *M.Sc.*

The results obtained by photographing on a rapidly moving photographic film the spectrum of the ordinary oscillatory spark with small self-induction have already been communicated to the Royal Society. The method has now been applied to study the spark when the self-induction of the circuit is gradually increased. On account of the feebleness of the light in these cases it has been found necessary to remove the prisms, photographing directly the image of the slit, in order to avoid the loss of light due to dispersion by the prism. It is still possible under these conditions to differentiate by their character the streamers through the metallic vapour from those through the air.

Condensers, whose capacity amounted to about one-third of a microfarad, were charged from a large Wimshurst machine, and the spark of 8 mm. length passed between metal electrodes. Self-inductances ranging in value up to 0·026 henries could be inserted in the circuit. The velocity of the photographic film was about 100 metres per sec.

The commencement of the spark is marked by a sudden and almost instantaneous luminosity of the air, showing on the photographs as a narrow vertical line. The duration of the luminosity is not appreciably affected even when the period of the circuit reaches a value of about 2×10^{-4} secs. This initial air discharge does not start quite simultaneously at all parts of the spark length. It is followed by another type of streamer through the air in which the duration is comparable with the interval between the oscillations; in some cases the oscillation is divided into more than one air-streamer.

After the initial air-discharge has passed, the light from the spark is chiefly due to the metallic vapour which is produced. The moment of vaporisation of the metal is simultaneous with the passage of the initial air-discharge. The first streamer in the metallic vapour often reaches to the centre of the spark. The slope of this streamer gives the velocity with which the vapour first produced is moving along the line joining the two electrodes. The luminosity of the metallic vapour afterwards consists of streamers starting from the electrodes. At the instantaneously positive electrode the luminosity of the streamers is of longer duration than at the negative; the streamers are not so numerous nor so distinct. There is not, however, the marked difference in the intensity of the streamers at the instantaneously positive and negative electrodes which was noticed in a previous paper on the spark with small self-induction. It is again found, however, that at the commencement of the spark, vapour is produced at both the positive and negative electrodes. Dark spaces at the electrodes separate the oscillations of the circuit and serve to measure the period of the oscillations.

The Velocity of the Metallic Vapour.—The measurements of the photographs show that the velocity of the metallic vapour first produced is smaller in the spark with self-induction than in the ordinary spark. In the case of mercury, for example, the velocity becomes 620 metres per second; the velocities found in the ordinary spark are 1,150 and 940 metres per sec. for two different types of spectral lines. This is more probably due to a reduced temperature rather than to the supposition that the quantity of metal vaporised is not sufficient in the former case to produce the difference of pressure required to make the velocity of diffusion attain its maximum value. The introduction of self-induction brings out the 'arc' lines of the metal. The evidence now obtained that the arc lines are due to, or accompanied by, a lower temperature confirms Lockyer's supposition which forms the basis of his researches on star temperatures.

When the self-inductance of the spark is increased, it is seen that during a single oscillation several streamers start from the electrodes; they are more distinct with magnesium than with lead, bismuth, or mercury. The streamers are too numerous and close together to make useful the supposition that they are due to harmonic overtones of the fundamental period of the circuit. The streamers are found to recur at definite intervals after the commencement of each oscillation of the spark, though they are not invariably present in every oscillation; generally not more than about ten apppear in a single complete oscillation. These intervals are the same in different photographs of the spark under the same conditions, but the individual streamers are not always reproduced in the same oscillation in different photographs.

Department of Cosmical Physics.

The following Papers were read:—

1. *On New Methods of obtaining the Spectra of Flames.* *By* G. A. Hemsalech, *M.Sc., D.Sc.*

The apparatus exhibited is a simplified form of the one which the author, in conjunction with M. de Watteville, has devised for the production of flame spectra. A glass bulb encloses a spark gap formed between electrodes of the metal whose spectrum it is desired to obtain. The lower part of the bulb is provided with one or more tubular openings, and the top communicates with a Bunsen burner in such a way that the air feeding the burner flows through the bulb. When powerful electric sparks (condensed) are allowed to pass between the electrodes, metal vapour issues from the latter and diffuses into the surrounding air. This vapour generally combines with the oxygen and nitrogen of the air, and the resulting product forms very finely divided particles, which to a great extent are in the ultra-microscopic state. These particles remain suspended in the air and are carried along with it into the Bunsen flame, where they give rise to the characteristic flame spectrum of the element under examination. In many cases it is preferable to supply the flame with the spray from a salt solution of the element. The solution is contained in a small porcelain crucible placed at the bottom of the glass bulb, and a condensed spark is taken from the surface of the solution by means of a Cu. or Pt. electrode. The spectra thus obtained are very similar to those given by the Gouy apparatus, and the new method has the advantage of not necessitating the use of compressed air. The application of these methods to the case of the oxy-coal gas, hydrogen, air-hydrogen, and oxy-hydrogen flames has enabled M. de Watteville and the author to study the flame spectrum of an element under various temperatures and other conditions. An examination of the iron spectrum carried out in this way has disclosed the presence of 'spark' or 'enhanced' lines in the cone of the Bunsen flame. On passing to flames of higher temperature these lines diminish in relative intensity, and they are nearly all absent from the oxy-hydrogen flame. Thus it appears that for iron the 'dissociating power' of the inner cone of the Bunsen flame is greater than that of any other flame here considered.

2. *Polar Lines in Arc Spectra.* *By* Dr. W. G. Duffield.

In a paper which appeared in the 'Astrophysical Journal' (27, 260, 1908) a list of lines occurring at the tips of the electrodes of a continuous current iron arc were chronicled by the writer. Direct comparison with a spark discharge showed a close resemblance in the ultra-violet between these lines and those occurring in the spark; this resemblance gradually disappeared as the region of longer wave-length was approached, the lines under discussion becoming fewer in number. The term 'polar' lines was suggested to distinguish those lines appearing at the tips of the poles from those in the centre of the arc or spark (for which the term 'median' lines seems suitable), and avoids the ambiguity introduced by the term 'spark' line when applied to the spectrum of a normal arc. Not all of the polar lines occur in the spark; a few are absent from it and others are weak in it. The paper also discusses the effect of density, pressure, chemical action, potential gradient, temperature, and molecular velocities upon this phenomenon, and the behaviour of median lines when polar lines appear near them. Fowler, who had previously[1] examined these lines in the region F to C, pointed out their identity with enhanced lines and those weakened in sun-spots, and considered that they might be regarded as high-temperature lines; but the writer's photographs, in which the intensities were the same on the two poles, did not support this view. A subsequent paper by G. A. Hemsalech and C. de Watteville[2] is of interest in this connection, because they find that 'enhanced' and polar lines constitute almost exclusively the spectrum of iron given by the low-temperature Bunsen flame. This is evidence that chemical action or electrical conditions are chiefly responsible for their appearance. Fabry and Buisson have also independently examined the polar lines in an arc, but they conclude that they are formed when the ions attain a certain velocity which may be produced either by a potential fall or an elevated temperature. Hartmann has discussed the conditions concerned with the production of the 'spark' line of magnesium $\lambda = 4481$ in an arc spectrum, and from its strong appearance in a weak arc he decided that temperature was not the criterion for its existence.

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3. *The Zeeman Effect in Sun-spots.* *By* Professor J. Larmor, *Sec. R.S.*

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4. *On the possible Existence of Steam in the Regions of Sun-spots.* *By* Rev. A. L. Cortie, *S.J.*, *F.R.A.S.*

At the Leicester meeting of the Association the probability of the lower temperature of the sun-spot regions relatively to the photosphere was derived from a comparison of the behaviour of the bands of titanium oxide in the spectrum of Mira Ceti, at a more or less brilliant maximum, and the bands of the same compound in the spectrum of sun-spots.[3] The question at present discussed is whether the reduction of temperature over a sun-spot is sufficiently great to permit the formation of water-vapour in the form of superheated steam. For more than twenty years in the observations of sun-spot spectra made at Stonyhurst in the red and yellow regions numerous lines have been recorded with the dispersion used as widened or affected in sun-spots, which are coincident with lines due to water-vapour. One obvious explanation is that true solar lines are so close to the water-vapour lines as not to be separable, even with very great dispersions, and that the widening is due to the solar lines. Using a much more powerful combination of telescope and spectroscope than the tele-spectroscope at Stonyhurst, Dr. Mitchell, of the Princeton Observatory, was unable to detect these lines as widened in the spectrum of sun-spots.[4] The region λ 5900–5950, which is very rich in such lines, has been carefully studied and measured on a photograph in the third order of a large flat-grating in the spectrum of a big sun-spot secured on July 31, 1906. The details of the measurements are set forth in a table. Of 91 lines measured, 64, or 70·3 per cent., are due to water-vapour, and of these 64, 29, or 45·3 per cent., are affected, either widened or darkened, in the sun-spot. In the photograph measured the sun-spot spectrum is not isolated from the photospheric spectrum. But in the photographic map of Professor Hale and Mr. Ellerman, in which the sun-spot spectrum is isolated, 16 of these 29 lines are present, the dispersion being much greater than that employed at Stonyhurst. Professor Fowler has shown[5] that a great number of the bands in sun-spot spectra are due to magnesium hydride, and Mr. Brooks,[6] from a laboratory study of this same spectrum, concludes that it cannot be produced without the presence of water-vapour. Hence it may be concluded that the lowering of temperature in the regions of sun-spots, in which the chemical

[1] *Monthly Notices*, 67, 154, 1907.
[2] *C.R.*, June 1908.
[3] *Astrophysical Journal*, xxvi. 2, September 1907.
[4] *Ibid.*, xxii. 1. p. 29.
[5] *M.N. R.A.S.*, lxvii. No. 8.
[6] *Proc. R.S.A.*, 80, No. 537.

compounds titanium-oxide and magnesium hydride are indubitably present, caused by the expansion of the escaping vapours, is sufficiently great to permit the combination of the oxygen and hydrogen to form water-vapour in the state of superheated steam.

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5. *Sun-spots and Solar Temperature.* *By* Professor E. T. Whittaker, *Sc.D., F.R.S.*

The majority of astrophysicists incline to the view that sun-spots are places of diminished temperature; this view is based on the observational evidence, which is (i) that chemical compounds are present in spots, (ii) that the 'arc' lines are widened and the characteristic 'spark' lines weakened in the spot-spectrum as compared with the ordinary Fraunhofer spectrum, and (iii) that the continuous background of the spot-spectrum has its maximum displaced towards the infra-red as compared with the continuous background of the Fraunhofer spectrum.

The writer observed with regard to (i) that the formation of chemical compounds from their dissociated elements may be brought about either by a fall of temperature or by a rise of pressure; with regard to (ii), that the observations of the high-level and low-level chromospheric spectrum show that 'arc' lines are associated with the high pressures of the lower chromosphere rather than with the low temperatures of the upper chromosphere; and with regard to (iii) that the differences between the continuous spectra of the spot and of the rest of the sun is analogous to the difference between sunlight as observed at noon and near sunset, the difference being in this case due to the extra depth of atmosphere through which the sunlight has to travel. It is concluded that the phenomena of the spot-spectrum are to be ascribed to relatively high pressure rather than to relatively low temperature.

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6. *Recent Researches on the Cause of Seiches.* *By* E. M. Wedderburn, *F.R.S.E.*

In the autumn of the year 1905 careful observations were made in Loch Earn by Professor Chrystal which throw much light on the effect of meteorological conditions on the denivellations of lakes. In addition to the three stationary limnographs employed to record the seiches, Dine-Shaw microbarographs were stationed at Ardtrostan (on Loch Earn), Loch Earnhead, and Killin (on Loch Tay). There was also at Ardtrostan a pressure anemograph. By means of the triad of microbarographs an indication could be obtained of the rate and direction of travel of the disturbances shown on the traces. Out of twenty-seven cases examined by Professor Chrystal, the disturbances travelled in a S.W. direction in twenty-two cases, and in a N.E. direction in five cases. The average velocity of propagation was about thirty miles per hour.

Comparison of observations in Lochs Earn, Treig, Ness, Lubnaig, Tay, and Garry (Inverness-shire), indicate that seiches are most frequent in lakes which are deep and straight, and also in those which run in the direction in which the microbarometric disturbances travel.

Possible causes of seiches, mentioned by Professor Chrystal, are as follows, viz.:—

(1) Earthquakes. The evidence from Loch Earn and Loch Ness is that earthquakes are not an effective cause of seiches. Against this must be set the great disturbances which are said to have occurred at the time of the Lisbon earthquake of 1755.

(2) Progression of the general system of isobars causing a release of static denivellation of the lake surface. Calculation shows that even in the most favourable circumstances a seiche produced in this manner must be of very small amplitude.

(3) Piling up of water at one end of a lake by winds. In deep lakes piling up of water by wind is small, owing to the readiness with which the return current takes place, and may be neglected in a consideration of the causes of seiches.

(4) Rapid flooding at one portion of a lake may in exceptional circumstances produce a seiche.

(5) A heavy rainfall may produce a seiche.

(*a*) By the gravitational effect of the precipitation.
(*b*) By the force of its impact.

(6) The impact of wind-gusts on portions of the lake may also cause a seiche.

The foregoing are causes which might produce seiches suddenly. The following causes might account for a gradual increment in the seiche amplitude:—

(i) Microbarometric fluctuations over portions of the lake surface of a period approximating to one of the seiche periods of the lake. The disturbing effect may be considerable even where there is no considerable disparity between the barometric period and the seiche period.

(ii) Periodic fluctuations in the direction and pressure of the wind. It is difficult in any individual case to say what is the precise effective cause of a seiche, as wind, rain, and barometric variations usually occur together.

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7. *Difference of Temperature in the Upper Atmosphere between Equatorial and Polar Regions. By* L. TEISSERENC DE BORT.

In former discussions of the observations made over the Atlantic on the 'Otaria,' and those made at Kiruna, near the Arctic Circle, by the French-Swedish expedition, I have shown that the difference of temperature between the Equatorial and the Arctic regions is very different at different altitudes. In the lower layers the temperature of the equatorial zone exceeds that of the Arctic regions by 25° C. This excess of temperature decreases as the altitude increases until at a height of 10 or 11 km. it is as warm over the Arctic Circle as it is over the equatorial zone. With further increase in height there is no further decrease in temperature over the Arctic Circle, because the isothermal region is reached. But in the neighbourhood of the equator the rapid decrease of temperature with increasing altitude still continues; the temperature becomes less therefore over the equator than it is at the same height over the Arctic Circle.

Recent balloon ascents made this year at Kiruna at the end of the winter give a general confirmation of these conclusions. They show that at a very cold period with temperatures below $-15°$ C. near the surface, the temperature in the upper regions is nearly the same as that found over the equatorial zone. There are indeed some days when the polar temperatures are lower than the equatorial, but this is a temporary phenomenon which occurs at the coldest time of the year. In equatorial regions, on the contrary, if one considers as the point of departure the region where the trade winds meet, near the thermal equator, there is, strictly speaking, neither winter nor summer.

No ascent to great heights has hitherto been made in Arctic regions during the warm season: we propose finally to fill up this gap. But what we know already of the decrease of temperature at different places, together with the observations made at St. Petersburg, enables us to count on temperatures sufficiently high in the upper layers, probably higher than $-50°$ C.

Thus during the greater part of the year it is sensibly colder by 10° or 20° C. in the equatorial regions at altitudes of 15 or 16 km. than in Arctic regions. This fact, anticipated by me some years ago, deserves to be taken into serious consideration in theories relating to the general circulation.

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8. *Note on the Manchester 'Ballons-Sondes' Ascents.* *By* W. A. Harwood.

In connection with the Howard Estate Observatory of the Manchester University, *ballons-sondes* ascents have been made regularly during the past year on the dates appointed by the International Committee.

The balloons are of fine sheet rubber, and carry light instruments of the type devised by Dines. These record pressure and temperature. The total weight of instrument and case being only two ounces allows the use of relatively small and inexpensive balloons.

The majority of the ascents have been made after sunset, to avoid possible errors due to solar radiation; but the similarity of the results obtained by day and night tends to show that the instrument is sufficiently ventilated to prevent serious errors being introduced from this cause.

The instrument was carefully calibrated before and after each ascent, the relation between deflection and pressure being determined for a number of different temperatures.

The results have been of fairly uniform type.

In general the temperature falls steadily at a slightly increasing rate up to a height of about 10 kms. The gradient then quickly diminishes to zero, or to a small positive or negative value.

The average height at which the isothermal layer was encountered is about 11·5 kms. This height is slightly greater (12 kms.) above anti-cyclones, and slightly less (11 kms.) above cyclones, as has been previously found.

The lowest temperature which has been recorded is $-65°$ C. on February 6, 1908, at a height of 11 kms.

The conclusion that the lowest temperatures are found above anti-cyclones has been verified, the average minimum temperature being $-55°$ C. compared with corresponding cyclonic temperature $-46°$ C.

On an average three-fourths of the instruments have been returned.

The usual practice has been to give the balloons a free lift, about 70 per cent of the total weight. This gives the greatest heights combined with the greatest percentage of balloons returned.

As might be expected the percentage of instruments found is greatest in anti-cyclonic weather. The average distance traversed by the balloons is about sixty miles, and the mean direction E. by S. Consequently the most favourable starting-point would be in the neighbourhood of Shrewsbury.

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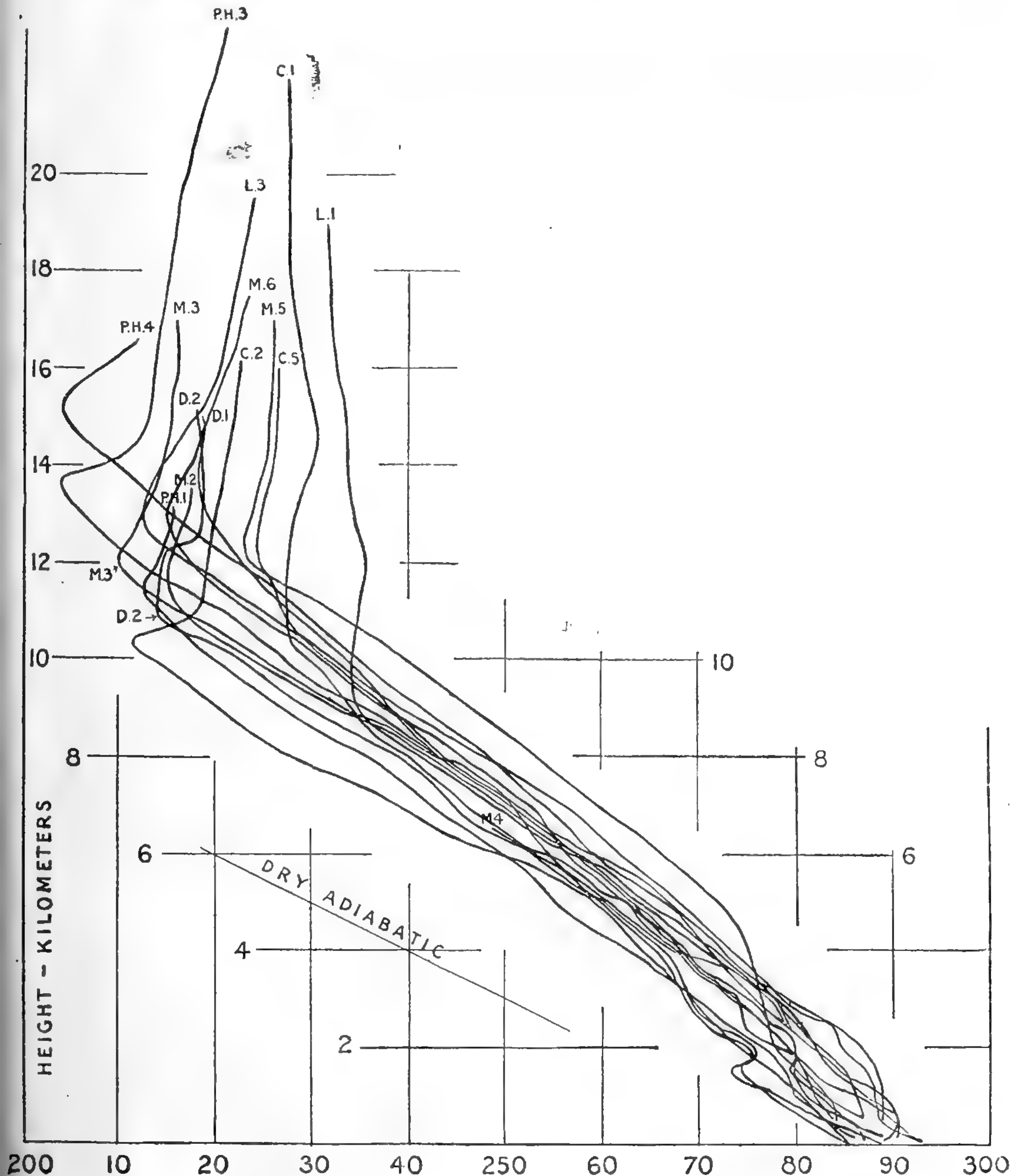
9. *The Results of the 'Ballons-Sondes' Ascents in the British Isles during the International Week, July 27–August* 1, 1908. *By* J. S. Dines.

The places of fall of the instruments were plotted on a map and exhibited as a lantern slide. Of the five stations from which ascents took place, it may be mentioned that Crinan is on the West Coast of Scotland, Pyrton Hill about fifteen miles south-east of Oxford, and Ditcham Park a little to the north of Portsmouth. It is generally found that the tracks of the several balloons sent up from the different stations on the same day are approximately parallel, and this was the case on the days of the international week, with the exception of July 29. On this day a high-pressure system was situated with its centre over the south-western part of the British Isles, and the direction of travel of the different balloons seems to have agreed closely with the circulation around this centre. On the other days of the week the high-pressure system was more remote.

The subjoined diagram shows the relation between the temperature (on the absolute scale) and height above sea-level (in kilometres). The numbers against the curves refer to the days, so that all ascents on the same day have the same number. The different stations are denoted by the letters. All the ascents were made near the time of sunset except C. 5. The temperature near the highest point in this case showed rather a sharp rise, and as this may have been due to the effects of insolation the upper part has been omitted from the diagram. The temperatures of the isothermal layer obtained last year in the corresponding period



STATIONS	DAYS
C.—Crinan.	1.—July 27.
M.—Manchester.	2.—July 28.
L.—Limerick.	3.—July 29.
P.H.—Pyrton Hill.	4.—July 30.
D.—Ditcham Park.	5.—July 31
	6.—Aug. 1.

were about 230° or 240°, which is considerably above those found this year. The two minima of 204° are the lowest that have been obtained in British.

ascents. The usual inversions were experienced in the first three kilos. above the earth's surface, after which the temperature fell steadily, in some cases the rate exceeding by a slight amount for a kilometre or more the dry adiabatic. (See C. 2 and D. 2.) In D. 2, C. 2, and P.H. 3 a very sharp rise of temperature is noticeable just above the coldest point.

Great differences are apparent in the temperature of the isothermal at different places on July 27. C. 1 and L. 1 are in moderately close agreement at about 230°, while P.H. 1 and D. 1 show a temperature of below 220°.

The difference between L. 1 and P.H. 1 amounts to practically 20°.

On July 31 the records obtained at Manchester and Crinan are practically identical for the isothermal.

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10. *Observations of Currents in the Upper Air of Egypt and the Sudan. By* Captain H. G. Lyons, *F.R.S.*

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11. *An Apparatus for illustrating, by Intermittent Vision, the Surface Movement of Air in Travelling Storms. By* R. G. K. Lempfert, *M.A.*

This apparatus, by the use of which intermittent vision of a succession of maps is obtained through parallel slits in a revolving drum, has been arranged at the Meteorological Office to visualise simultaneously the trend of a 'storm' across the map and the surface movement of air within the storm area.

The consecutive maps have been drawn for intervals of one, or at most two hours. When placed in position, they form an inner lining to a drum, with slits in its upper part, attached to a revolving horizontal, after the manner of the toy known as a 'zoetrope.' The position of the storm[1] is represented on successive maps by the isobars which show the barometer distribution. The movement of the air within the storm area is shown by arrows, each one of which represents a 'step' in the motion of the air. As the drum is revolved, the isobaric systems appear to travel across the map and the arrows to move forward, tracing out the 'trajectories' or paths of the air.

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12. *On the Asymmetrical Character of Whirlwinds. By* Paul Durandin.

WEDNESDAY, SEPTEMBER 9.

The following Papers were read:—

1. *Changes of Atmospheric Density in Storms. By* J. I. Craig, *M.A.*

A mass of air which expands without gaining heat necessarily experiences cooling, and this mechanical cooling is now generally admitted by meteorologists to be the chief cause of rain. Such an expansion occurs when air is transported from a lower to a higher level. The paper showed that a similar expansion takes place in front of the trough of depressions of both the cyclonic and the V-shape, and that there is a certain amount of correspondence between the region of greatest surface dilatation and that of heaviest rainfall. In rear of the trough the dilation is negative, on the whole, but with isolated positive regions—a fact which may help to account for the 'passing showers' generally found in rear of baric depressions.

[1] *The Life History of Surface Air Currents.* London: H.M. Stationery Office, 1906.

The time-rate of dilation being $\frac{1}{\Omega}\frac{D\Omega}{Dt}$, where Ω is the volume of a given mass, may be expressed as $-\frac{1}{\rho}\frac{D\rho}{Dt}$, where ρ is the density and the differentiation operates along the path of the air mass considered.

To apply this method one must have at his disposal the history of the air-density along the trajectory. Hence one is led to make use of the material discussed by Dr. W. N. Shaw, F.R.S., and Mr. R. G. K. Lempfert.[1]

An advantage of the method indicated is that it permits of an estimate of the upward velocity of the air, at least near the surface. The hydro-dynamical equation of continuity may be written in the form

$$\frac{\partial\rho}{\partial t} + u\frac{\partial\rho}{\partial x} + v\frac{\partial\rho}{\partial y} + w\frac{\partial\rho}{\partial z} + \rho\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) = o$$

or

$$\frac{1}{\rho}\frac{D\rho}{Dt} + \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = o$$

where D/Dt has the same signification as above. Of the quantities involved in the last equation

$\frac{1}{\rho}\frac{D\rho}{Dt}$ may be found numerically at any locality, as above;

$\frac{\partial u}{\partial x}$ may be computed by constructing a synoptic chart of the eastward component velocity; and

$\frac{\partial v}{\partial y}$ may similarly be computed from a chart of the northward velocity; so that the fourth term may be found numerically.

A theoretical example for the particular case of uniform velocity and constant incurvature of the wind round circular isobars is given. If the dilation vanishes over the surface, the value of the upward velocity for small heights above the ground is

$$w = \frac{Vz}{r}\operatorname{Sin} a$$

where V is the velocity of the wind, z is the altitude, a the angle between the wind and the isobars, and r is the distance from the storm centre.

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2. *The Meteorology of the Winter Quarters of the 'Discovery,'* 1902–1904. *By* Dr. W. N. Shaw, *F.R.S.*

The author gave an account of the meteorological results obtained from the discussion of the observations at the winter quarters of the 'Discovery' in latitude 77° 50′ 50″ S., longitude 166° 44′ 45″ E., for the period February 9, 1902, to February 15, 1904, and on the sledge journeys of the Expedition, as published by the Royal Society in 1908.

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3. *Results of some Physical Observations taken on the National Antarctic Expedition,* 1902–1904. *By* L. C. Bernacchi.

The 'winter quarters' of the ship 'Discovery' were situated in lat. 77° 50′ 45″ S., long. 166° 44′ 30″ E.

[1] The examples shown were taken from *The Life History of Surface Air Currents*, by W. N. Shaw, F.R.S., and R. G. K. Lempfert. Meteorological Office Publication, No. 174.

The magnetic and other physical observations conducted on the shore close to the ship extend over a period of nearly two years.

The 'Discovery' 'winter quarters' were to the south-east of the south magnetic pole, the mean absolute declination being about 152° E. From the photographic records by the Eschenhagen magnetometers the general character of the regular diurnal variation of declination is clearly shown, the movement being five or six times as large as that at Kew; even during the months when the sun is continuously below the horizon the diurnal range remains large—at least double that at Greenwich at midsummer.

The seasonal change in the type of the diurnal variation is very small. In temperate climates generally the changes of declination during the day are conspicuously larger and more rapid than during the night. At 'winter quarters' there is no such marked difference.

The extreme positions are reached at about 9 A.M. and 7 P.M., and are totally different from those customary. The absolute declination observations indicate an apparent decrease of about 26′ between mean of observations May–December 1902 and mean May–December 1903, the horizontal force observations an apparent increase of 0·0013 C.G.S. between mean April–December 1902 and mean April–December 1903, and the inclination an apparent decrease of about 7′ between mean May–December 1902 and mean May–December 1903. The horizontal force at 'winter quarters' was about a third of that at Kew, but the range of the diurnal inequality about 50 per cent. greater than at Kew. The type also varies very little with the season, and is totally different from that at temperate stations.

Vector diagrams have been made for 'winter quarters' for the whole year, and for the seasons midwinter (May to July), equinox (March, April, September, October), and midsummer (November–January). The differences between these diagrams and the vector diagrams for Kew and Falmouth are remarkable. There is much less asymmetry than in England, the direction of motion is anti-clockwise, and there is very little difference in type for the different seasons. The most striking peculiarity in the diurnal inequality in all the elements is the large size of the fundamental or 24-hour Fourier 'wave' as compared with the harmonics of shorter period.

'In order to determine the position of the south magnetic pole by means of all the declination observations taken at "winter quarters," sledge journeys, and at sea, the results have been plotted (by Captain L. W. P. Chetwynd, R.N.) and the direction of the magnetic meridian as indicated by the observations extended towards the magnetic pole. These lines of direction intersect within a space triangular in form. The radius of the circle inscribed in the triangle measures about thirty-eight geographical miles, and the centre of the circle indicates the probable position of the pole, and is in lat. 72° 50′ S., long. 156° 20′ E.

'All the inclination results were plotted on a chart and lines of equal inclination drawn, from which the probable position of the pole is indicated to be in lat. 72° 52′ S., long. 156° 30′ E. The agreement between this position and that determined by the declination results is remarkable, and may be considered as corroboration of the results.

'The mean of the two positions, viz., lat. 72° 51′ S., long. 156° 25′ E., is, in all probability, a close indication of the centre of the polar area.'[1]

The results of the pendulum observations, taken with three separate quarter-meter invariable pendulums, give values all slightly in excess of the theoretical.

Accepting 981,200 (centimetres/second^2) as the value at Kew, the probable mean value deduced from all observations combined for 'winter quarters' is 982,985, the theoretical value being 982,963.

The most interesting outstanding feature is the large difference between the results obtained at 'winter quarters' during the winter months, July, August, September, on the one hand and those obtained during February, the end of the

[1] 'Magnetic Results,' *Physics*, vol. i., Royal Society.

antarctic summer, on the other. A possible explanation may be the large northward movement of ice occurring in the antarctic summer prior to February.

The paper also dealt very briefly with the results of tidal observations and atmospheric electricity.

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4. *On the possible Connection between Earthquakes and Great Waves in distant places.* *By* Rev. H. V. Gill, *S.J.*

In a paper read at the Royal Dublin Society [1] two years ago it was shown that there are grounds for the supposition that, under certain conditions, an earthquake in one locality may well be the immediate occasion of the occurrence of one or more succeeding shocks in other places on the earth's surface symmetrically placed with respect to it. This view was based on the fact that great earthquakes frequently cause a 'wobble' in the rotation of the earth. The effect of this is to produce a strain in other portions of the earth's mass, and a tendency for movable matter to shift its position, thus precipitating approaching earthquakes. An examination of earthquake records showed that this series of reactions may often have taken place. In the present paper the same principles are invoked to show that, in the same way, an earthquake may give rise to a water wave at a distant place, thus accounting for the genesis of waves otherwise difficult to explain. These principles were illustrated by experiments with hollow tops containing movable matter, such as steel balls and melted wax.

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5. *Some Particulars of the British Association Storm of* 1908. *By* Dr. W. N. Shaw, *F.R.S.*

The author exhibited the original records of pressure, of direction and force of the wind, and of rainfall at various stations in connection with the Meteorological Office during the passage across the British Isles of the deep depressions which crossed the Irish Sea during the night of August 31–September 1, 1908.

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6. *The Great Snowstorm of April* 25, 1908. *By* Miss C. O. Stevens.

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7. *On the Velocity of the Reducing Action of Electrolytic Hydrogen on Arsenious and Arsenic Acids when liberated from the surface of different elements.* *By* W. Thomson.

These experiments were commenced with a view to finding the velocities at which arsenic is liberated as arseniuretted hydrogen (AsH_3) from solutions of arsenious and arsenic acids respectively when using cathodes of different elements.

The experiments were made by passing, during intervals of two and a half minutes, the hydrogen containing arseniuretted hydrogen liberated from the cathode through drawn out hard glass tubes accurately graduated as regards diameter and heated to redness near the drawn out portion by which the arseniuretted hydrogen was decomposed, liberating arsenic in the elemental condition which deposited on the drawn out portion of the tube (which was kept cold by running water) as a dark metallic-looking mirror, the amounts of arsenic thus deposited being measured by the density of these mirrors as compared with standard mirrors for each period of 2½ minutes till no further mirror was deposited during one interval.

Fifty units of arsenic were employed for each experiment dissolved in 30 c.c. dilute sulphuric acid, each unit consisting of 0·000,000,5413 gramme, roughly

[1] XI. No. 11, 1906.

about $\frac{1}{2000000}$ of a gramme of elemental arsenic, that amount being sufficient to produce a well-defined mirror of arsenic on the drawn out tube.

The apparatus previously described by me,[1] which consists of a porous pot with platinum foil outside as anode and the element under examination as cathode inside the porous pot, was used in these experiments and the following elements were tried as cathodes: lead, zinc, cadmium, tin, silver, graphite, iron, platinum, aluminium, gold, cobalt, nickel, and palladium.

The above order represents their efficiency in removing arsenic from solutions of arsenious acid, the first being the most efficient, but this order does not hold good for efficiency in removing arsenic when it exists in the form of arsenic acid, for whereas the metals lead, zinc, cadmium, tin, and silver all reduce arsenious acid with the same velocity, only 41 per cent. of the arsenic acid present in the cathode chamber is converted into arseniuretted hydrogen by a zinc cathode in 25 minutes, while with a lead cathode 98 per cent. is reduced in the same time and under the same experimental conditions. Again, silver which with arsenious acid effects the reduction with a velocity equal to the first four mentioned metals fails when used as a cathode to liberate any arsenic as AsH_3 from arsenic acid. The supertension hypothesis put forward by various writers utterly fails to explain these results. Palladium with a comparatively high supertension (0·46 volt) stands at the bottom of the series both as regards arsenious and arsenic acids, while silver which has a low supertension (0·15 volt) reduces arsenious acid with a velocity equal to that of lead or zinc. Iron in this respect is remarkable with the lowest but one supertension (0·08 volt). It effects the reduction of arsenious acid with a velocity nearly equal to lead and stands next to lead in its capacity for reducing arsenic acid.

Lead has a slightly lower supertension than zinc, yet lead, as already mentioned, is far more efficient in the reduction of arsenic acid than zinc.

From the estimations made by collecting the arsenic evolved in intervals of two and a half minutes the first four metals gave a constant for a unimolecular reaction.

[1] *Memoirs and Proceedings of the Manchester Lit. and Phil. Soc.*, vol. xlviii., part iii., p. 17.

Section B.—CHEMISTRY.

President of the Section.—Professor F. S. Kipping, D.Sc., Ph.D., F.R.S.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address:—

On taking the Chair of this Section my first duty is to express my personal thanks to the Council of the British Association for having chosen me to fill this position of honour.

At this meeting the Association is enjoying, not for the first, but for the fourth time, the generous and genial hospitality of the citizens of Dublin; it is my privilege, on behalf of all the members of this Section, to tender our cordial thanks to our hosts for giving us this opportunity of meeting again in the capital of Ireland.

During the past few months we have read in the daily journals—and we sincerely hope it may be true—that there are signs of the commencement of a great development of the resources of this Island; as such a desirable event must be closely connected with, and, indeed, may even be dependent on, the vitality of the chemical industries of the country, the moment seems opportune for the consideration of a subject which has a direct bearing on both commerce and chemistry.

Although this Section is chiefly occupied with matters relating to pure science, the discussion of industrial questions is also regarded as one of its important functions; it does not attempt to distinguish pure from applied chemistry, and any problem which concerns either is deemed worthy of its attention.

From this point of view I propose to consider whether any steps can be taken to place the chemical industries of the United Kingdom of Great Britain and Ireland in a more prominent position than that which they now occupy in the world of commerce.

The subject is not new; it has been dealt with by many, but principally by those more directly interested—prominent members of the Society of Chemical Industry, who are far better qualified to express opinions on commercial matters than am I. It is perhaps presumption on my part to attempt to add anything to what has been said by such leaders of industrial chemistry, but I propose to deal with the subject from a very different standpoint—namely, from that of the teacher in the class-room and laboratory. Even if I fail to make a single suggestion of immediate practical value, the question is one of such magnitude and so many-sided that I feel justified in bringing it under the notice of this Section. It is not merely a matter of money, of a few millions or of a few tens of millions sterling. There are few branches of industry to which chemistry, in one way or another, is not of supreme importance. Whether we look to the great shipbuilding interests, dependent on the progress of metallurgy; to our cotton and linen trades, where cellulose reigns supreme; to our dye-houses or to our breweries, or to any other industry, great or small, there do we find problems in chemistry awaiting solution, and the nation which solves them will not only progress in civilisation and contentment, but will also justly claim to have taken a leading part in the advancement of science.

It is not then in any grudging spirit of envy that we approach this question; recognising the splendid work of men of other countries, rejoicing in the services which they have rendered to the world at large, our only desire is not to lag behind in the general intellectual and industrial advance of nations.

It is unnecessary to trouble you with any detailed comparison of the position which we occupy to-day with that which we have taken in the past. The fiftieth anniversary of the epoch-making discovery of mauve was held only two years ago, and the proceedings are still fresh in our recollection; the pæans of congratulation addressed to the discoverer (now, alas! no longer with us) were marred by a plaintive note, a note of lamentation over our lost industry, the manufacture of dyes. The jubilee of the founder of the colour industry in this country was also the occasion for pronouncing its funeral oration. If this were the full extent of our loss we might bear it with equanimity; but it is not so much what has already gone as what is going and what may go that are matters of such deep concern. Those who doubt the seriousness of our condition may find statistical evidence, more than sufficient to convince them, in the technical journals and in the Board of Trade reports of recent years.

The facts there disclosed show that in the manufacture of 'fine chemicals,' including perfumes, alkaloids, and crude coal-tar products, as well as dyes, the decadence of our industry is far advanced; in the case of heavy chemicals our position, perhaps, is not quite so serious at the present moment, but the future is dark and threatening. Chemical industries are so intimately connected and dependent on one another, that the fate of one may determine the fate of all; the by-product of one process is often the raw material of another. Who, then, can deny that the patience, perseverance, and high scientific skill, which have built up the colour industry abroad, if applied, as they have been and are being applied, to the manufacture of heavy chemicals, will not soon defy all competition from less progressive countries?

Such a possibility is full of national danger. It has been pointed out—and the prophecy cannot be regarded as unduly pessimistic—that from present indications a time will arrive when we shall be dependent on outside sources, not only for our food-supply, but also for our means of self-defence. When nitrates are exhausted, when nitric acid and ammonia are prepared from the components of the atmosphere, when all chemical industries have been so highly developed abroad that they have completely vanished from these Islands, and when their loss has reacted on all our other important industries, then, indeed, shall we feel the pinch of poverty; then, indeed, must we submit to national decay.

Is it possible to remedy the present unsatisfactory state of affairs, and to guard against an ominous future?

During the Perkin Jubilee celebrations Professor Carl Duisberg answered this question, in so far as it concerns the coal-tar colour industry, by an uncompromising negative. In an able and interesting speech he pointed out that, although the Briton is in general a practical man, he is lacking in patience, in the power of waiting for success; he expects to be compensated in hard cash, and at once, for his work or for his capital outlay. The German, on the other hand, is primarily a theorist possessing endless patience, and works without any immediate prospect of pecuniary reward; he has now learnt to be practical as well, but not at the expense of his ideals. It is to this happy combination of qualities that Professor Duisberg ascribes the success of his countrymen in the coal-tar colour industry—a success which he considers we are powerless to emulate, with which it would be futile for us to try and compete.

With this view that our chemical industries must submit to gradual extinction, even when it is held by so high an authority, we cannot and must not agree; if one nation can learn to be practical, we—the four nations of these islands—one or all, can learn to be plodding and patient, and to appreciate the importance of theory. We may be encouraged in our efforts to do so by the opinions of others, countrymen of Professor Duisberg, eminent in pure or applied science. Professor Ostwald, discussing this subject, said that he was sure the difficulties were considerable only in the beginning,[1] while Professor Lunge, in an address to the Royal Institution,[2] made use of the following words: 'Seeing that in pure science the people of Great Britain have never lagged behind any other nation, and that, on the contrary, the land of Newton and Faraday has been a beacon to all others at more than one epoch, there is absolutely no valid reason why she should now, or at any other time, be behind any other in the combination of science with practice.'

Here, indeed, is encouragement, and from one who has had ample opportunity for studying the conditions which obtain in this country. Surely, therefore, we ought to have some confidence in ourselves and try our best to regain a strong and healthy position rather than fold our hands in a spirit of hopeless resignation.

The new Patent Act which came into force this year, and for which the country is so much indebted to the strenuous advocacy of Mr. Levinstein and Sir Joseph Lawrence, seems to many to have inaugurated a new era, and to have removed one of the principal causes of the decline of our chemical industries; if this be so, it is all the more important that the representatives of chemical science should be ready and willing to join hands with the manufacturers in order to assist in the process of regeneration.

The principal changes which have been introduced by the new law are, of course, familiar to all. The most important one, which came into operation on August 28 last, is that which requires that the article or process which is protected by the patent must be manufactured or carried on to an adequate extent in the United Kingdom after the expiration of four years from the date of the patent. If this condition is not fulfilled, any person may apply for the revocation of the patent.

Some of the results of this amendment, and some indications of the great industrial changes which it will bring about, are already obvious. Foreign firms or individuals who hold British patents and who have not sufficient capital to work them in this country, or who do not think they are worth working here, are attempting to sell their British patent rights. Others are building or buying works in Great Britain, and it has been estimated that in the immediate future a sum of at least 25,000,000*l*. of foreign capital will have been thus invested in order to comply with the new law.

We need not stop to consider the economic effects of this transfer of capital on the general trade of this country, but we may well pause a moment in order to try and forecast the consequences of these new conditions in so far as they concern our chemical industries.

The prospective establishment of branches of two of the largest German chemical works at Ellesmere Port and at Port Sunlight respectively are already matters of common knowledge, and it may be presumed that these firms will avail themselves to a large extent of British labour. If this be the case, and if they are successful—as they, no doubt, will be—the complaint that the inferior technical education of our artisans is responsible for our lack of success will thereby be proved to be groundless. Even if we admit that at the present time the British workman is an inferior operative in a chemical works, and only capable of undertaking the less-skilled labour, these firms will gradually raise a considerable number of trained men who will be ready to undertake more responsible duties under our own manufacturers when the good time comes; a school for chemical operatives will be created in our midst, and, as in the past, we shall reap the benefit of knowledge and experience brought to our shores. It also seems reasonable to expect that, as is the case abroad, these works will be equipped with laboratories and staffed by chemists, although possibly only so far

[1] *Jour. Soc. Chem. Ind.*, 1906, 1019.

[2] March 15, 1907.

as is necessary for routine work. Many of these chemists may settle permanently in our midst, become members of our Chemical Society and Society of Chemical Industry, and thus infuse us with their patience and perseverance. It is not beyond the bounds of possibility that these great firms may even employ British chemists in their works, if we can supply men sufficiently well trained to be of value. On the other hand, as experience seems to have shown that industrial chemistry cannot succeed with imported scientific labour, it is not very probable that many posts in the laboratory will be filled by our countrymen, who, in this connection, must be regarded as foreigners.

Now at the present time most chemical products can be manufactured more cheaply abroad than here, otherwise we should not have any reason to consider our position. Dr. Duisberg told us that even when an important firm in England had a licence to work all the British patents of two of the largest German colour works, merely paying for the privilege a small percentage of the net profits, it failed to take any advantage of the opportunity. If, then, in this free-trade kingdom production is cheaper than abroad, the foreign firms which have branches here will be in a position superior to that which they now occupy in their own countries. If, on the other hand, owing to inefficient labour, higher wages, freights, and other economic conditions, production is more costly, the superior efficiency and scientific organisation of these foreign firms will nevertheless enable them to command our home market with the goods made here, and to cut us out in the world market, as they do now, with those made abroad.

The conclusion which thus seems forced upon us is, that, although the new Patent Act will prove to be of great value in many respects, it will do little to foster British chemical trade and the development of British chemistry; it places us on an equality with other countries as regards patent rights, and thus remedies an outstanding grievance; but, unless we have something to patent, this equality will be valueless and our chemical industries will continue to decline, possibly more rapidly than heretofore.

Let us therefore pass in review the other causes which have been suggested as contributory to our failure; after eliminating those connected with freights and tariffs, and with the alleged supineness of the Government in assisting industry, matters which may be left to the manufacturers to deal with, there still remain several which are well within the purview of this Section.

These are: (1) the unsatisfactory condition of secondary education; (2) the nature of the training which is given to chemists in our universities and other institutions; (3) the insufficiency of the time and money devoted to research in the manufacturing industries; (4) the lack of co-operation between manufacturers and men of science.

There are some who believe that the first of these is the primary, if not the sole, cause of our weakness; that if our secondary education were placed on a sound basis all the other evils would disappear of their own accord; that a steady and broad stream of well-trained boys from the secondary schools would afford ample material from which good chemists could be fashioned in the universities and colleges; that these trained chemists would be greedily seized by the manufacturers, whose minds had been widened by improved educational methods; and once installed in the works these chemists would have no difficulty in persuading their employers to spend time and money on research work in co-operation with the leaders of science.

Whether such desirable and far-reaching results would in fact follow if our system of secondary education were very much improved it is impossible to predicate; but there is no doubt that at the present time we are moving in an exactly opposite direction.

The shadow of the cypress rests upon our chemical trade, and manufacturers do not see their way to employ chemists; students are not attracted to chemistry as a profession because there are so few openings; without an ample and increasing supply of such students chemical industry must continue to decline, and as a necessary consequence the development of pure chemistry is cramped and hindered to a far greater extent than is generally realised.

In a Presidential Address to the Chemical Society last year Professor Meldola discussed the position and prospects of chemical research in Great Britain, and in view of the importance of the subject and the able manner in which it had been treated the Council of the Society ordered the publication of five thousand copies of his Address for distribution among the members of various public bodies. We were told in this Address that many of our universities are distinct failures as centres of chemical research, and that the output of original work from our colleges, polytechnics, and similar institutions is emphatically not representative of the productive power of the teachers there employed. The causes of the failure of our universities were only lightly touched upon, and I propose to refer to them later; but in the case of our other institutions they were more fully discussed. May I venture to draw attention to one cause, which I believe is by far the most effective drag on research in the vast majority of such institutions not of university rank? It is simply the lack of those more advanced students who, while gaining valuable experience in the methods of research, would also render useful assistance to their teacher. The governing body of the institution may not realise the importance of research; the Principal, as, alas! is sometimes the case, may throw cold water on such work; the teacher may be overburdened with routine duties, and he may be most inadequately remunerated; if, however, the research spirit is strong within him, he would overcome all these difficulties were there any prospect whatsoever of success; but what chance has he when he must do everything himself, even to washing out his own test-tubes? Provide him with a few advanced students, and he would doubtless find time to undertake the necessary pioneer research work, which would then be extended and developed with their assistance.

It might be suggested that an efficient and enthusiastic man would soon attract a number of research students. This, no doubt, is true as regards the universities, but it must be remembered that a polytechnic or other institution which does not grant degrees can hardly expect to compete with a university as a centre for research; all those students who intend to undergo a so-called 'complete' course of study—that is to say, all who are likely to become capable of undertaking research work— naturally proceed to one of the degree-giving universities. There are not enough students to go round, to satisfy the research requirements of the teachers, and the principal reason is—the limited demand for trained chemists on the part of the manufacturers.

Even of the small number of those who leave our teaching institutions fairly well trained in research, how many have a chance of passing into works and directly advancing applied science? A very small proportion indeed. Most of the better ones drift into other posts, become demonstrators, emigrate—anything rather than wait on with the prospect of accepting as works-chemist a salary which, meagre though it be, may be stopped altogether if dividends are low.

With whom rests the responsibility for this state of affairs? Is it with the teachers, and, if so, is it because they are incapable of training chemists or because their system is at fault?

To answer this question it is necessary in the first place to arrive at some conclusion as to the kind of training which is required for the future works-chemist. On consulting the opinions of the manufacturers it would seem that they attach great importance to what is called the 'practical side'; they believe that, in addition to a knowledge of theoretical chemistry, the prospective works-chemist should also have some acquaintance with engineering, should understand the apparatus and machinery used in the particular manufacturing operations with which he is going to deal, and should have had practical experience in working the given process. It is from this point of view that we build and equip large technological chemistry departments, such as those in the Universities of Birmingham and Leeds and in the Manchester Municipal School of Technology, departments fitted up with complete apparatus and machinery for carrying out operations on a miniature manufacturing scale.

The arguments in favour of this view, that it is a hybrid chemist-engineer who is required in a chemical works, seem to me to be fundamentally unsound, and the kind of training suggested by them for the works-chemist can only result in the production of a sort of combined analytical machine and foreman. A two or three years' course of science, followed by one year's practical work in the dye-house, in paper-making, or in some other technological department, is quite inadequate if the student trained in this way is expected to do anything beyond routine analytical work and supervision.

We cannot possibly expect such a poorly trained Jack-of-all-trades to run a chemical works successfully in the face of competition directed by a large staff of scientific experts in chemistry and in engineering. It is no use spending immense sums of money on expensive machinery of the newest type in order that the works-chemist may be able to tell his future employer that the machinery used in his employer's works is completely out of date. In the course of time, moreover, unless expenditure is practically unlimited, the reverse conditions will obtain, and the technological department of the university or other institution will become more of the nature of a museum of antiquities. The great cost of the upkeep and of the working of such plant is also a very serious matter. The conditions in a chemical works cannot be successfully imitated in a university or polytechnic; attempts to do so can only lead to mistaken conclusions, and thus have the effect of rendering the works-chemist quite helpless when he passes from the elegant models of his educational apparatus to the workaday appliances of the manufactory.

Here, it seems to me, we touch the bed-rock of our trouble. The state of our chemical industries must be attributed to the erroneous views which have been and still are held as to the functions, and consequently as to the training, of a works-chemist. We have failed to realise that industrial chemistry must be based on a foundation of continuous and arduous research work. In the past we have sent out from our universities and other institutions students who no doubt were qualified to undertake routine analytical work, but the great majority of whom knew nothing of the methods of research. We are doing the same to-day. Just when a student has reached a stage at which his specialised scientific training should begin his course is finished, and whether he has been to a university or to a polytechnic matters little; he joins the band of those who subsist on but who do nothing to advance chemical industry. He enters a works; the manufacturer does not realise exactly what his chemist ought to do, but he expects some immediate results, and in consequence is generally disappointed; the lack of success of the chemist is put down to his ignorance of practical matters, and there is an outcry for technical education; science is most unjustly discredited, and any suggestion of spending money on research work is scouted as a mere waste.

The consequence is that if there is a scientific problem which intimately concerns all the members of some large industry what course do they adopt? Through their trade journal, and as an association representing a total capital of which I should not like to hazard a guess, they offer a bronze or possibly a silver medal, or may even offer the extravagant sum of 20*l.*, to the happy person who will provide them with a solution. It is difficult to imagine the class of solvers to whom these princely rewards may appeal, more difficult still to believe that any useful result can be attained, and it is almost incredible that such methods should be adopted by any influential industrial organisation. This way of attempting to get research work 'on the cheap' is certainly not unknown even in more enlightened countries, but that is hardly a sufficient justification for its employment.

Contrast these methods with those adopted by the Badische Anilin- und Soda-Fabrik and Meister, Lucius, & Brünig in their attempts to solve the problem of the commercial synthesis of indigo. Could there be a greater antithesis? If five thousand copies of Brunck's paper on this subject[1] could be circulated among the manufacturers of this country—a task which might be fittingly undertaken

[1] *Ber.*, 1900, I. lxxi.

by the Society of Chemical Industry—the study of the truly magnificent results attained by the systematic application of pure science, and of the indisputable evidence of their commercial value, might prove an object-lesson far more effective than argument for the accomplishment of a sorely needed reform.

Now if we are to meet successfully the very formidable scientific and commercial organisation opposed to us in chemical industry, we must perforce adopt the methods of our competitors; not only must we learn patience and perseverance, but we must also call to our aid the best brain-power available. We must recognise clearly that the scientific works-chemist, the only man who is likely to make discoveries of commercial value, must be thoroughly trained in the methods of research by those best qualified to do so, and we must not imagine that when he enters the works he should or could immediately become an engineer and a commercial expert; his place is in the research laboratory. The practical man—that is to say, the man who has a thorough and useful knowledge of some particular manufacturing process—must be trained under practical men in the works, and we must not imagine that a course of evening classes will convert him into an expert chemist. The ideal man who combines high scientific training and sound practical knowledge cannot be produced unless the period of his education is extended to half a life-time, and even then only through the co-operation of the chemistry teacher and the manufacturer.

Admitting the truth of these statements—and I do not think that they can be successfully controverted—we have now to consider what steps can be taken to provide these highly trained works-chemists, and to ensure for them a cordial reception on the part of the manufacturers.

The first fact which we have to bear in mind is that the great and rapid development of chemistry in recent times has lengthened the period which is required for the collegiate study of the subject. In order to acquire the necessary knowledge of facts and theory, and afterwards to devote even the minimum time to gaining experience in research methods, the future works-chemist must be prepared to continue at the university or other institution during at least five years. The course of study during the first three years might be on the lines now adopted by many of our universities for the B.Sc. pass examination, but to grant this degree in one or two subjects only, and then to call it an Honours degree, is in my opinion a serious mistake, as is also the admission of research work at this stage, both of which proceedings lead to far too early specialisation. The pass degree should be regarded merely as an indication of a sound general education in science, and the future works-chemist should then devote at least two years more to research and to special work in chemistry, on the results of which the Honours degree might be awarded. Every encouragement in the form of low fees, free admission, research scholarships, and so on, should be offered to such students, according to their merit and circumstances, in order that they may prolong their studies; the cost of these remissions or awards would not be very serious and the money would be well spent. Teachers should then refuse to recommend, and manufacturers should refuse to employ, as a works-chemist, any student who had not passed through such a course satisfactorily, unless it was understood that he was only expected to undertake routine analysis or work outside the research laboratory. By thus extending the period of training, and making research work compulsory as far as possible, a great deal would be gained; pure science would reap an immediate benefit from the investigations of the students—as has been the case abroad—and this stimulus would necessarily react on industrial chemistry; the manufacturers could be assured that they were being supplied with men of the right type; they would soon come to recognise that fact, and the demand for works-chemists would expand. In the laboratory of the works the manufacturer would then have the opportunity of gauging the capabilities and special leanings of every chemist on his staff. Those who were best fitted for directing operations in the works could be trained on the spot, as they could not possibly hope to be trained in any university or polytechnic; those who proved to be the best research chemists would, of course, remain in the laboratory working out scientific problems. Organisations of this kind could not fail to command success, and the opsonic curve of our chemical industries would soon begin to rise.

There is one institution, not a teaching body, which might greatly assist in this movement: I refer to the Institute of Chemistry of Great Britain and Ireland. This body desires and claims to represent chemistry, not only in these islands, but in all our dominions, and also to exercise some supervision or control over public appointments. It examines in chemistry and grants diplomas, and claims that its examinations are a test of practical ability rather than of theoretical knowledge. I have not a word to say against the character of these examinations, but to imagine that the Institute of Chemistry qualification is the hall-mark of a chemist is ridiculous. An average student can obtain the diploma after three, or at the very most four, years' work subsequent to matriculation, and more easily than the London B.Sc. (external). Here, again, it should be recognised that the present Institute of Chemistry qualification is only a step in the training of a chemist; the permission to present a thesis for the associate examination should be withdrawn, and good research work should be insisted on in the case of all candidates for the fellowship. It would then be possible to distinguish between those who are capable routine chemists and those who might be expected to advance pure and applied science. It is certainly a grave matter for an institution entirely controlled by chemists to set such a bad example by ignoring the necessity of research work; if all our official chemical appointments and many of our posts in works are to be filled by men who have done no independent scientific work, the results will be most serious; the research habit and the research method are not easily acquired without assistance, and therefore it is all the more important to make use of this assistance while it is within reach, and before the budding chemist begins to believe that he has nothing more to learn.

As a necessary corollary to making research compulsory in the training of works-chemists, all our important teaching institutions must afford ample opportunities for such work, and measures must be adopted to guard against that failure of some of our universities as centres of research which was pointed out by Professor Meldola.

Such failure, whatever may be the contributory causes, must be principally due to the absence of sufficient interest in research work on the part of the professor, and it certainly seems surprising, at first sight, that in these days many such professors are to be found; but it must be remembered that although by members of this Section research work is regarded as the highest and most important of all professorial duties, this is not always the view of those who make an appointment to a chair.

In selecting a professor there are many other considerations which come into play: his ability as a teacher in the class-room and laboratory; his qualifications as a popular exponent of science; his power of organisation; his bearing towards his colleagues and his students—all these matters are of great and direct importance to a university, and it is not to be wondered at that a man highly qualified in these accessories may sometimes be chosen even though he may take no special interest in research work.

The results of such an appointment, however, cannot fail to be most prejudicial to the highest interests of the university and of the country; the chemistry department becomes a chemistry school, but not a school of chemistry.

Unfortunately, moreover, the results extend over a long period: this raises another question which certainly requires attention if we are to become more efficient.

It is far from my object to create any gratuitous insecurity of tenure in chairs of chemistry, but is it not desirable that in our teaching institutions the conditions of all appointments should include a superannuation clause? Not that a rigid age-limit should be introduced, but there should be a possibility of bringing about the retirement of those who for any reason can no longer adequately fulfil their duties. When, owing to the lapse of time, such retirement became necessary, the aged and honoured professor, pensioned by a grateful university, might still retain an intimate connection with its scientific life; as emeritus professor, with a research laboratory at his disposal, he might remain to advise and encourage his youthful successor even when the duties of teaching and the general supervision of a department had become too arduous.

It cannot be suggested that my remarks on this delicate topic are inspired by the impatience of youth or by freedom from personal consequences; the time when superannuation becomes desirable may arrive for one and all, and I have ventured to draw attention to the matter simply and solely because of its grave importance in connection with the subject of my Address. The country cannot afford to allow periods of inactivity or decadence in our seats of learning, and the interests of the individual must be subordinated to those of the nation.

Even if by adopting the above suggestions the training of our chemists is improved, and all our higher educational institutions become permanent and active centres of research, the manufacturers may still remain unresponsive, what can be done in other ways to bring about the active co-operation of pure and applied science?

The great proportion of the original work now done in this country, judging from the published records, is absolutely free from any utilitarian bias; the time, brain-power, and money devoted to this work are considerable, and the results from a scientific point of view eminently satisfactory. If even a fraction of the same skill and energy were brought to bear under proper conditions on problems of applied science, who can doubt but that the effect on our chemical industries would be one of vast importance? And yet it is the rarest possible occurrence to find any record of research work undertaken with a commercial object even in the natural home of such records, the 'Journal of the Society of Chemical Industry.'

One reason for this may be that the discoveries made in the works-laboratories are not given to the world at large, but are quietly and lucratively applied in some secret manufacturing process. Another reason, unfortunately the more probable one, may be that nearly all the principal research workers are completely shut off from any industrial influences.

Now the worker in pure science, unaided by the advice of the manufacturer and business man, has little chance of solving any important technological problem, except as the result of accident; he has not the requisite acquaintance with commercial conditions, does not realise the enormous difference between operations on the laboratory and the manufacturing scales, or, if he does so, is unable to enter fully and with confidence into questions of fuel, labour, and so on which often determine the success or otherwise of a process. Further, much of the research work of direct commercial value concerns methods for reducing the cost of processes already in operation, and demands an intimate practical knowledge of these processes.

It is obvious, therefore, that, even if all the research capacity of the country were henceforth devoted to purely technical matters, any great improvement in our industries could hardly be anticipated without the active co-operation of the manufacturers.

Now it has been stated[1] that the authorities of the Manchester Municipal School of Technology intend to undertake investigations for local manufacturers and merchants in connection with difficulties which may be met with in their works or business. This method of securing the interest and support of those engaged in applied chemistry may or may not be workable according to the conditions under which such co-operation is carried out. The staff and the laboratories of a university or polytechnic cannot be placed at the unrestrained and gratuitous disposal of any manufacturer who is in some trivial difficulty, nor can the choice of the subjects to be investigated be decided by the governing body. If however the arrangements, pecuniary and otherwise, are left entirely in the hands of those directly concerned, namely, the manufacturer and the responsible head of

[1] Levinstein, *Jour. Soc. Chem. Ind.*, 1903, 815.

the chemistry department, the scheme should then prove exceedingly valuable, and should be adopted as widely as possible. It should be understood, and the fact might even be advertised by the governing body, that for purposes of research work in applied chemistry—but not of course for analytical work—the laboratory of the university, college, or polytechnic is, under certain conditions, at the service of the manufacturers; that although primarily and unswervingly devoted to work in pure science, such institutions recognise that, for their own interests, they must do all they can to assist chemical industries.

It might be thought that these conditions prevail at the present time and that any manufacturer, if he so choose, may consult the university staff on any problem in which he is interested. Possibly this is true to a limited extent, but in most institutions the members of the staff are restrained from undertaking any outside work; in others, such work may only be done with the sanction of the authorities.

These conditions, of course, are only laid down because the governing body believes that they safeguard the interests of the institution, and if it were shown that their enforcement is really contrary to those interests they would soon be abrogated. Many or all such authorities readily permit the members of their staff to undertake outside examination work because they consider this course to be to the advantage of their institution; but how incomparably more important is the object of gaining the confidence and support of the manufacturers.

Pray do not let it be imagined that this is some subtle scheme for increasing the pecuniary rewards of the teachers. I greatly fear that to many of those who are now engaged in research work the suggestion that they should give some attention to applied chemistry would be very distasteful, simply because it would involve an immediate encroachment on the time, already far too limited, which they are able to give to the immediate scientific problem which is one of their principal joys in life. To those who might have fears of this kind I would point out that there would soon be some compensation; once the co-operation of the manufacturers is secured, the demand for research chemists would expand, and the laboratories would be filled with students whose help in pure science would be invaluable.

The possible objection that the teaching staff would devote too much time to applied work and neglect other duties is one which could be left for the governing body to deal with unsparingly. If the institution took some percentage of all extraneous remuneration, or any similar arrangement were made, the funds thus provided could be used for increasing the staff of assistants and demonstrators—a most desirable reform in itself.

One of the greatest advantages of a working arrangement such as that here indicated would be that, like the method already suggested, it would lead to the evolution of what is otherwise almost unattainable—namely, men thoroughly trained in both science and practice. The research students of the teaching institution, engaged on a given problem for a manufacturer, would of course be allowed to study its practical aspects in the works; on the other hand, works-chemists, with considerable practical experience, would be granted permission to proceed to the university laboratory, where they would study the problem with the assistance of the highest scientific knowledge, and acquire further training in the methods of research.

Combinations such as these could hardly fail to lead to valuable results, which would form the subject of patents; the monopolies thus acquired would place the manufacturers in a favourable position, and the revival of our chemical industries would follow in due course. There is nothing Utopian in this scheme, and there are no great initial difficulties to be overcome; it may be set in operation by the manufacturer, and possibly also, as will be indicated later, by the worker in pure science. Reading between the lines certain records which have recently appeared in the science journals and the patent lists, it may even be inferred that such arrangements are already in force in one of our large industrial centres.

There are other ways in which it might be possible to obtain the active co-operation of the manufacturers. Any individual or firm interested in a problem of applied science might be invited to found a temporary research scholarship at the university or other institution for the definite object of the particular problem in question. The maximum period during which such a scholarship would be tenable might be fixed beforehand, so that the financial liability of the founder would be limited and proportionate to the importance of the object in view. The holder of the scholarship might be nominated by the university, or by the founder and the university jointly, and suitable conditions would be drawn up to ensure the interests of the founder; he would of course have the benefit of all the results of the work, and would secure the patent rights of any new invention, subject possibly to the payment of a small percentage of the profits to the university and to the holder of the scholarship. During the tenure of the scholarship, the holder, and also the founder, would have the advantage of the scientific knowledge of the university; the scholarship holder would also be allowed to gain practical experience in the works, and, if successful, there is little doubt but that he would have the option of working the process on the large scale and of obtaining permanent employment under satisfactory conditions. After a given period the scientific results of the work would be published through the usual channels in the ordinary way.

This idea of applied research scholarships had taken shape in my mind when I happened to come across a book recently published in the United States, called 'The Chemistry of Commerce,' in which I found that a similar proposal had been made by the author, R. K. Duncan, Professor of Industrial Chemistry at the University of Kansas. The scheme is there worked out in some detail, and a form of legal agreement to be signed by the university authorities and by the founder of the 'Industrial Fellowship' is suggested.

Thinking it would be of interest to know how the plan had worked out in practice, I wrote to Professor Duncan and received a reply a few weeks ago. He very courteously informed me that five industrial fellowships had already been established in his laboratories, that the agreements for two additional ones were being prepared, and that he might have obtained more but wished to proceed conservatively; also that he had no reason to doubt the entire practicability of the scheme, and that experience had shown that the terms of the agreement could be made more favourable to the university than those which were first drawn up. One of the new conditions is that the industrial fellowship holder shall give two hours a week gratuitous instruction in the work of the chemistry department—an arrangement which has proved to be of great inspirational value. The fellowships are tenable during two years and are of the value of \$500 or \$1000 per annum.

It is too soon to be able to form any opinion as to the commercial importance of the work carried out under this scheme, but it is obvious that the foundation of such scholarships for the study of general or special problems in applied chemistry is most desirable. One of their great advantages would be that they might be founded by those manufacturers who cannot afford permanently to engage a research chemist. Large and successful firms like the United Alkali Company, Brunner, Mond, & Co., and many others which can employ a staff of chemists, are of course eminently capable of managing their own affairs without outside assistance or advice, and it is only for those which are less prosperous that the foregoing suggestions are made.

The great benefits which are conferred on pure science by the open research scholarships at present available afford some indication of what might be done for industrial chemistry by the foundation of such scholarships in applied science. There are, no doubt, scattered over the country many men who possess originality and inventive talent, and who have practical experience in industrial operations, but who have not been sufficiently trained in science; if it were possible to attract this dormant talent by means of open scholarships it might be directed into proper channels instead of being allowed to run to waste.

It is easy to say how money might be spent advantageously, but very difficult to suggest how the funds for such open scholarships should be raised. An appeal to the manufacturers by this Association or by the Society of Chemical Industry might meet with some response, and it is also possible that public bodies might render assistance. If the Government of Bengal, under the spur of dire necessity, can subsidise research work on indigo, and if our county councils can offer scholarships for dairy work, and grants for experiments on turnip-growing, bee-keeping, and so on, our city and borough councils might award scholarships in applied chemistry for subjects of especial importance to the dominant trades of the district. By so doing they would be utilising to the best advantage the chemistry departments of our universities and polytechnics.

I noted a few moments ago that practically all the published research work of this country has no direct reference to any industrial problem ; nevertheless the results of this work are often of such a character that they might be of considerable technological importance. New reactions are discovered; new or improved methods of preparing known compounds; new facts as to the conditions under which important general reactions occur; and, needless to add, a great many new compounds are prepared.

Now, abroad, all or nearly all such matters are protected by patents, generally taken out by some firm of manufacturers. To the uninitiated it seems absurd to think that there is money in the great majority of such patents, and yet it is obvious that the employment of this system must pay in the long run. Why should it not be adopted in this country—at any rate to a limited extent to start with ?

If all those who are engaged in purely scientific research work would seriously consider the desirability of obtaining provisional protection for any discovery which they may make, and would then consult some manufacturer or industrial expert with whom the further development of the matter might be undertaken, there is reason to believe that in some cases at least the patent might prove to be a commercial success.

The examination of the therapeutic action of compounds discovered in our laboratories is also a possible means of assisting our chemical industries; the matter is not so trivial as it may seem; a monopoly in the manufacture of some valuable medicinal preparation would serve as a *point d'appui* from which more important operations could be undertaken.

Unfortunately the investigation of the physiological action of new preparations is a matter of some difficulty in this country, as it is to some extent connected with vivisection in the public mind; we may poison rats with impunity, and even create an organisation for their extermination, but we may not individually try the effect of a new compound on a rabbit.

In drawing this Address to a conclusion I cannot but feel that my suggestions may seem utterly inadequate to the attainment of those important results which are so greatly to be desired. If so, I can only plead that more drastic measures are hardly available, and that even under the most favourable circumstances improvement can take place only very slowly. Whatever differences of opinion may be held as to the details of any scheme for regaining our lost ground, the main lines seem to be clearly indicated. The workers in pure science must recognise that it is their duty to do all they can to promote the industrial welfare of their country; the manufacturers must concede the paramount importance of science and the impossibility of dispensing with its counsels. Guided by these principles and by a spirit of cordial co-operation, a sustained and strenuous effort on the part of the leaders of chemical industry and of chemical science can hardly fail to accomplish the end in view.

In elaborating this Address I have enjoyed the advantage of the criticisms and suggestions of my friend and relative Professor Perkin, F.R.S., to whom my sincere thanks are here expressed.

The following Papers and Reports were then read:—

1. *Synthetical Experiments in the Terpene Series.* *By* Professor W. H. PERKIN, *F.R.S.*

2. *The Preparation of Camphor from Turpentine Oil.* *By* Dr. C. WEIZMANN.

During the last six years many methods for the manufacture of camphor by the removal of hydrochloric acid from pinene hydrochloride have been developed. The hydrochloride is heated with aliphatic or alicyclic amines, such as methylamine, dimethylamine, piperidine, or with an alcoholic solution of ammonia, under high pressure.

The chief feature of these processes appears to be high pressure, a temperature of 200° to 250°, and the presence of a large excess of the dehalogenising agent. This agent need not necessarily be a strong base, but it appears to be important that the pinene hydrochloride should be maintained in solution during the reaction. Laboratory tests show that many of these processes yield from 70 to 80 per cent. of the theory. As the result of experiments in the laboratories of Manchester University it was found that when pinene hydrochloride is heated with glacial acetic acid and from 5 to 10 per cent. of its weight of zinc chloride, it is readily converted into *iso*bornyl acetate, with evolution of hydrochloric acid gas. The zinc chloride appears to act catalytically, and large quantities of pinene hydrochloride can be converted into *iso*bornyl acetate with comparatively small quantities of zinc chloride.

The acetate is then hydrolysed by boiling with alcoholic sodium hydroxide. The alcohol is distilled off and the *iso*borneol separates out as white crystals.

3. *Brazilin and Hæmatoxylin.* *By* R. ROBINSON.

4. *The Dynamic Isomerism of Oxymethylene Camphor Derivatives.* *By* Professor W. J. POPE, *F.R.S., and* JOHN READ.

5. *Benzyl Sulphoxide: a possible Example of Tautomerism.* *By* J. A. SMYTHE, *Ph.D., D.Sc.*

The reaction between hydrochloric acid and benzyl sulphoxide in various solvents has been studied. The products include four to six of the following bodies: benzaldehyde, benzyl chloride, benzyl mercaptan, benzaldehyde mercaptol and the sulphide, disulphide and disulphoxide of benzyl. Consideration of this action has led to the view that benzyl sulphoxide exists in solution in tautomeric forms, and from these two forms it is possible to build up five equations, which give a complete explanation of the reaction with hydrochloric acid, not only qualitatively but also quantitatively. The agreement of the quantitative results with those calculated from the equations is held to justify the hypothesis upon which the equations are founded.

Thus in solution one may regard benzyl sulphoxide as existing in the two tautomeric forms as expressed by the equation:—

$$\begin{matrix} C_6H_5.CH_2 \\ C_6H_5.CH_2 \end{matrix}\Big\rangle SO \rightleftarrows \begin{matrix} C_6H_5.CHOH \\ C_6H_5.CH_2 \end{matrix}\Big\rangle S,$$

the equilibrium depending upon the temperature, the nature of the solvent, and the concentration of water.

6. *The Action of Halogens upon Aromatic Hydrazines.* *By* F. D. Chattaway, *D.Sc., F.R.S.*

The actions which take place when the halogens are brought into contact with primary aromatic hydrazines are so violent, unless special precautions are taken, and such large amounts of tarry matters are formed, that they have been investigated comparatively little, and in consequence the formation of the many different substances which are produced when the conditions of interaction are altered has never been accounted for satisfactorily.

The complicated changes which occur all depend, however, upon a progressive substitution of hydrogen attached to the nitrogen, followed by a breaking down or intra-molecular rearrangement of the N-substituted hydrazines thereby produced.

When a halogen acts upon an aromatic hydrazine one of the hydrogen atoms of the $-NH-NH_2$ group, probably one in the $-NH_2$ group is replaced,[1] a nitrogen halogen derivative being produced which at once undergoes what is in fact the typical diazo decomposition—for example :—

$$\begin{array}{c} C_6H_5-N-H \\ | \\ H-N-H \end{array} \rightarrow \begin{array}{c} C_6H_5-N-H \\ | \\ H-N-Br \end{array} \rightarrow \begin{array}{c} C_6H_5 \\ | \\ H \end{array} + \begin{array}{c} N \\ ||| \\ N \end{array} + \begin{array}{c} H \\ | \\ Br \end{array}$$

Hydroxyl ions much accelerate the rate at which this decomposition occurs, while hydrogen ions correspondingly diminish it.

When halogens therefore act upon aromatic hydrazines in presence of alkalis, hydrocarbons, the hydrides of the aromatic groups present in the hydrazines, are almost exclusively produced. When, however, an excess of halogen is employed a relatively small amount of the N-mono-substituted hydrazine undergoes further substitution before disruption can take place and a dihalogen N-substitution product is formed, which, like the mono-substitution product, is unstable in presence of alkali and breaks down similarly, a mono-substituted halogen derivative of the hydrocarbon formed in the first action being produced—for example :—

$$\begin{array}{c} C_6H_5-N-H \\ | \\ H-N-Br \end{array} \rightarrow \begin{array}{c} C_6H_5-N-Br \\ | \\ Br-N-H \end{array} \rightarrow \begin{array}{c} C_6H_5 \\ | \\ Br \end{array} + \begin{array}{c} N \\ ||| \\ N \end{array} + \begin{array}{c} H \\ | \\ Br. \end{array}$$

The N-mono-substituted hydrazines being far more stable in presence of acids, when these are present this replacement of a second halogen atom takes place to a much greater extent, and the whole of the hydrazine may thus be converted into the N-disubstituted derivative, which then may, according to conditions, undergo the diazo decomposition or yield a diazonium salt, thus :—

$$\begin{array}{c} C_6H_5-N-Br \\ | \\ Br-N-H \end{array} \rightarrow \begin{array}{c} C_6H_5-N-Br \\ ||| \\ N \end{array} + HBr.$$

The diazonium salt may, if suitable means are adopted, be isolated,[2] but, as the interaction of halogen and hydrazine is usually very vigorous and accompanied by considerable evolution of heat, it is generally decomposed, giving rise to tarry matters.

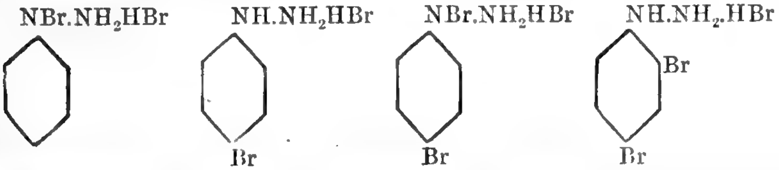
In presence of a considerable excess of hydrochloric or other strong acid the NH_2 group is to a large extent protected[3] against the action of the halogen and substitution takes place most readily in the $-NH-$ group. The nitrogen halogen compound thus produced is of the type of the acyl amino compounds, and

[1] This, as in other similar cases, is without doubt effected by the addition of two atoms of the halogen, followed by the elimination of a molecule of halogen hydride.

[2] Chattaway, *Trans. Chem. Soc.*, 1908, **93**, 852.

[3] This is probably due to the addition of halogen necessary for substitution to take place being prevented by the combination of the NH_2 group with the acid.

under the influence of the acid undergoes the intramolecular rearrangement characteristic of these compounds, whereby the halogen passes into the para or ortho position in the nucleus. Mono and disubstituted hydrazines are thus produced—for example:



Further substitution into the remaining ortho position has not been observed, and probably cannot be effected, since the substitution of halogen so lessens the basicity of the hydrazine that the NH_2 group is attacked by preference; indeed the yield of mono or disubstituted hydrazine is never satisfactory, diazonium salts and their decomposition products always being produced in large quantity.

The author has recently shown[1] that when the required amounts of bromine are added to aromatic hydrazines dissolved in acetic acid, diazonium perbromides, which are thus N-tribromosubstituted hydrazines, are produced quantitatively. The replacement of hydrogen in the $-NH.NH_2$ group can thus be carried to completion—for example:

$$\begin{array}{c} C_6H_5-N-H \\ | \\ H-N-H \end{array} \rightarrow \begin{array}{c} C_6H_5-N-H \\ | \\ Br-N-H \end{array} \rightarrow \begin{array}{c} C_6H_5-N-Br \\ | \\ Br-N-H \end{array} \rightarrow \begin{array}{c} C_6H_5-N-Br \\ | \\ Br-N-Br \end{array}$$

Each of these substitution products can undergo the typical diazo decomposition quantitatively when the conditions are favourable. Thus by the action of bromine upon phenyl hydrazine we can obtain either benzene or bromobenzene, nitrogen and hydrogen bromide or bromine being eliminated thus:—

$$\begin{array}{c} C_6H_5-N-H \\ | \\ H-N-Br \end{array}, \qquad \begin{array}{c} C_6H_5-N-Br \\ | \\ Br-N-H \end{array}, \qquad \begin{array}{c} C_6H_5-N-Br \\ | \\ Br-N-Br. \end{array}$$

Other compounds besides these simple ones may be formed—for example, from among the products of the action of bromine on phenyl hydrazine, in addition to benzene and bromobenzene, p- and m-dibromobenzene and 1, 2, 4 and 1, 3, 5 tribromobenzene have been isolated, as well as azobenzene and diphenyl; the formation of all these products can be simply explained by the theory of the reaction here put forward. It is, moreover, entirely in harmony with all that has been observed in the oxidation of the aromatic hydrazines.

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7. *Some Reactions of Dichloro Urea.*
By F. D. Chattaway, *D.Sc.*, *F.R.S.*

Urea is so well known and has been so much investigated that any new simple substance obtainable from it possesses quite an unusual amount of interest. Such a new substance is found in dichloro urea, which, leaving out of consideration the derivatives of ammonia itself, is one of the simplest possible compounds containing halogen attached to nitrogen. It is produced when chlorine is passed into a cooled saturated aqueous solution of urea. Action takes place without any considerable development of heat, and dichloro urea crystallises out as a white powder consisting of small transparent plates. It can be preserved for a

[1] *Proc. Chem. Soc.*, 1908, **24**, 172.

considerable time in a dry atmosphere, although it is not a very stable body. It is comparatively safe to handle, and promises to be of considerable use as a synthetic agent, as it is easily soluble in water, alcohol, and ether, and is very reactive. Its composition shows that it has the formula $CON_2H_2Cl_2$, and having regard to its mode of formation as well as to the structure of urea itself, its constitution is most probably represented by the formula $OC{<}^{NHCl}_{NHCl}$.

By means of this formula its formation and such of its reactions as have yet been studied can be explained. The other theoretically possible chloro substitution derivatives of urea, though probably formed in the reaction between chlorine and urea, have not so far been isolated.

When dichloro urea is produced, although two molecules of hydrogen chloride are formed, very little heat is developed, and it must therefore be an endothermic compound and might be expected to be highly explosive. When heated, however, it does not itself explode, but decomposes at about 83°, with liberation of nitrogen chloride, which latter may detonate with great violence if not allowed to escape, and if the temperature is raised a few degrees higher, as, for example, when dichloro urea is heated in a test tube over a water-bath.

Dichloro urea gives all the characteristic reactions of a typical nitrogen chloride; for instance, it liberates iodine from hydriodic acid, chlorine from hydrochloric acid, and reacts with alcohol, forming ethyl hypochlorite, urea being in each case re-formed.

Dichloro urea is distinguished from most other substituted nitrogen chlorides by the readiness with which it is hydrolysed, nitrogen chloride, carbon dioxide, a little nitrogen, and ammonium chloride being formed. If the compound is dissolved in water or kept in a moist atmosphere, this hydrolysis takes place slowly at the ordinary temperature, and becomes very rapid at about 30° C.

It is probable that in this reaction a mono-substituted ammonia is first produced thus:—

$$CO{<}^{NHCl}_{NHCl} + 2H_2O = CO{<}^{OH}_{OH} + 2NH_2Cl.$$

But if so, it apparently can only exist momentarily, as nitrogen chloride is at once liberated. The formation of the end-products of the reaction can be explained by assuming that this monochloro ammonia immediately breaks up into ammonia and nitrogen chloride.

$$3NH_2Cl = 2NH_3 + NCl_3,$$

which then to some extent react in the ordinary way, forming nitrogen and hydrogen chloride, the latter at once combining with the free ammonia and allowing the remaining nitrogen chloride to escape, as this does not react with ammonium chloride.

Both acids and alkalis accelerate the rate of hydrolysis, and further alter the nature of the end-products by hindering or furthering the secondary reaction between the ammonia and the nitrogen chloride. In presence of dilute acids the ammonia is at once fixed, and the reaction between it and the nitrogen chloride, with its accompanying liberation of nitrogen, is prevented; all the chlorine contained in the dichloro urea is therefore liberated as nitrogen chloride. In presence of alkalis, on the other hand, the reaction between the ammonia and the nitrogen chloride goes on to completion since the hydrochloric acid formed in it is at once fixed; no nitrogen chloride, therefore, is set free since twice as much ammonia as is required to decompose it is present.

The reaction between dichloro urea and a solution of caustic potash is very energetic; nitrogen is liberated with effervescence, the excess of ammonia and the alkaline carbonate formed remaining dissolved in the liquid. The action, which is quantitative, is expressed by the equation

$$3CO{<}^{NHCl}_{NHCl} + 12KOH = 3K_2CO_3 + 2NH_3 + 6KCl + 2N_2 + 6H_2O.$$

This behaviour of dichloro urea with alkalis affords an insight into what occurs when urea is decomposed either by an excess of alkaline hypochlorite or hypobromite. The course of this reaction has never hitherto been explained, although it has received an unusual amount of attention on account of its furnishing a ready method of estimating the quantity of urea present in a liquid. In this reaction the urea is without doubt converted into a chloro or bromo urea, which is at once hydrolysed in the manner above described. It is possible that in presence of excess of hypochlorite or hypobromite a tri- or tetra-substitution product may be produced, the formation and decomposition of which can be formulated easily, but this does not affect the essential character of the reaction, which is one of halogen substitution followed by hydrolysis of the substituted urea and interaction between the resulting compounds.

A reaction which indicates the use to which dichloro urea may be put in the synthesis of simple carbon and nitrogen rings is that between it and ammonia.

When ammonia in excess is added to an aqueous solution of dichloro urea, hydrolysis, accompanied by liberation of nitrogen and formation of carbonate, occurs, but in addition diurea $CO\left\langle\begin{matrix}NH\,NH\\NH.NH\end{matrix}\right\rangle CO$ is produced, and separates in considerable quantity as a sparingly soluble crystalline powder. This is the first direct synthesis of diurea from urea itself, the compound having been previously obtained from ethyl carbonate and hydrazine.

This adds another to the very few reactions known by which nitrogen atoms can be made to link up together, and further affords an exceedingly simple synthesis of hydrazine.

Diurea, when heated with excess of strong sulphuric acid to a little above 100° C., is easily hydrolysed, carbon dioxide escapes, and hydrazine sulphate is produced. This crystallises out perfectly pure in almost theoretical amount on cooling and adding a little water.

Dichloro urea can be prepared from urea and converted into diurea so easily, and the latter can be hydrolysed so quickly, that the reactions afford a synthesis of hydrazine more adapted to prepare a small quantity than any yet described. The operations involved are so simple and can be carried out so quickly, that they are also excellently suited for showing the synthesis of hydrazine as a lecture experiment.

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8. *Report on Dynamic Isomerism.*—See Reports, p. 112.

FRIDAY, SEPTEMBER 4.

Discussion on the Nature of Chemical Change. Opened by Professor H. E. Armstrong, *F.R.S.*

The following Papers were then read:—

1. *Note on a Volatile Compound of Cobalt with Carbon Monoxide. By* Dr. Ludwig Mond, *F.R.S.*, Dr. Heinrich Hirtz, *and* M. Dalton Cowap.

In a previous paper,[1] published by one of us in conjunction with Dr. Carl Langer and Dr. F. Quincke, entitled 'Action of Carbon Monoxide on Nickel,' p. 752, we stated that 'numerous experiments made to obtain similar compounds of

[1] *Journal of the Chemical Society*, 1890, p. 749.

carbon monoxide with other metals, notably with cobalt, iron, copper, and platinum, have only led to negative results.' In a later paper,[1] published by one of us in conjunction with Dr. F. Quincke, we announced the formation of iron carbonyls, which were subsequently more fully described by one of us in conjunction with Dr. Carl Langer.[2]

In continuing the experiments with cobalt, and taking advantage of the method of Sir James Dewar for facilitating the formation of nickel carbonyl, by acting upon the finely divided metals by carbon monoxide under a high pressure and correspondingly high temperature, instead of working at ordinary pressure and ordinary temperature, as we had hitherto done, we succeeded in obtaining small quantities of a cobalt carbonyl when the pressure was raised to 50 atmospheres and the temperature to 150° C., and the quantity formed was considerably increased by raising the pressure to 100 atmospheres and the temperature to 200° C.

The cobalt oxide was prepared from a pure oxalate, free from nickel and iron, by heating to about 200° C. The cobalt oxide was filled into a steel retort, which was fitted with two steel pipes for the gas circulation. All iron parts were lined with copper, so as to prevent the action of carbon monoxide on the iron. This retort was heated in an oil bath. Behind the outlet valve we fixed a small gun-metal cylinder, which contained a filter of flock asbestos, and behind this we had an additional filter of cotton-wool in a glass tube. From there the gases had to pass a condensing bottle, and the spent gases were burnt at the outlet. The cobalt oxide was placed into the retort and reduced with hygogen at 5–10 atmospheres pressure, and at the lowest possible temperature. A slow current of carbon monoxide was then passed through the apparatus at 100 atmospheres pressure. The temperature of reaction lies between 150° C. and 200° C. Both filters were kept at 50° C. by means of warm water. The condensing bottle was cooled in ice. In this bottle we obtained large orange crystals of the cobalt carbonyl.

The analysis of these crystals was made by decomposing them with bromine water. The carbon monoxide was measured, and the cobalt estimated in the solution. The result was:—

Co.	CO.	Co/CO.
0·0744 gr.	0·1597 gr.	1:3·96
0·0582 gr.	0·1115 gr.	1:4·03

We conclude therefore that this compound is $Co(CO)_4$, corresponding to the liquid nickel carbonyl.

The cobalt carbonyl is gradually decomposed in air, leaving a deep violet substance, which has not yet been investigated. The crystals are best preserved by sealing them in a glass tube under hydrogen or carbon monoxide. The cobalt carbonyl is very slowly attacked by non-oxidising acids, as hydrochloric or sulphuric. The reaction is accelerated by the presence of an oxidising agent. The carbonyl is quickly, almost instantaneously, decomposed by oxidising acids, such as bromine, chlorine, nitric acid, and the corresponding cobalt salt is formed under elimination of carbon monoxide, according to the following equation:—

$$Co(CO)_4 + Br_2 = CoBr_2 + 4CO.$$

The cobalt carbonyl is insoluble in water, but more or less soluble in the several organic solvents, such as carbon bisulphide, ether, naphtha, alcohol, and nickel carbonyl. If these solutions are kept standing for some time, or if they are warmed, decomposition sets in. These and other solutions and their products of decomposition have not yet been investigated.

The specific gravity measured by the suspension method at 18° C. is 1·827, but we do not regard this figure as final, as the substance is so easily decomposed, and if only kept for a few hours the specific gravity increases considerably, due to decomposition. The vapour tension *in vacuo* could not be measured with certainty, owing to decomposition. The vapour tension at 15° C. measured 11 mm., but

[1] *Journal of the Chemical Society*, 1891, p. 604.
[2] *Ibid.*, p. 1091.

at 25° C. decomposition could be proved, which was very marked at 35° C., so that we are not sure if there was not already a slight decomposition at 15° C. In a carbonic oxide atmosphere the decomposition commences at about 40° C. to 45° C., and is complete at 130° C. to 135° C., leaving metallic cobalt.

The melting-point lies between 42° C. and 46° C. We could not estimate it more exactly, owing to decomposition.

The authors reserve for themselves the right to further examine this reaction with other metals.

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2. *The Structure of the Open Chain Hydrocarbons. By* Professor W. J. Pope, *F.R.S., and* William Barlow, *F.R.S.*

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3. *The Dynamics of Chemical Action and the Meaning of Valency. By* H. Bateman.

The valency of a chemical element or radical is a number which indicates the degrees of freedom for departure from the existing state of motion of the charged particles which constitute the element or radical; its value depends simply upon the nature of the *stability* and instability of the state of motion.

An atom whose valency is different from zero is supposed to be capable of an infinite number of states of steady motion, and of so adjusting its motion as to enter into chemical combination with other atoms.

When two atoms combine the particles can be supposed to describe orbits round one another, with the result that the stability of the motion of the compound system is altered. If such atom loses a degree of freedom we can represent the effect by a bond connecting the two atoms.

An ideal atom can be constructed in which the spectrum is invariable for all states of motion consistent with given types of stability or constraints.

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4. *Colloidal Chemistry. By* H. R. Procter, *M.Sc.*

See Reports, p. 201.

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5. *The Influence of Colloids and Colloid Suspensions on the Solubility of Carbon Dioxide in Water. By* Dr. Alex. Findlay.

The problem of the absorption of gases, more especially oxygen and carbon dioxide, by blood is one which has exercised the minds of physiologists and physicists for many years, the view generally held being that the gases are retained in the blood largely owing to the formation of chemical compounds. With regard to the absorption of CO_2, the reputed alkalinity of the blood and the consequent formation of carbonate and bicarbonate have been held chiefly responsible for the increase in solubility of CO_2 in blood as compared with that in a corresponding salt solution. Recently, however, various investigators (Holber, Farkas, Fraenkel &c.) have shown that blood is 'water neutral,' in which case the generally held view regarding the absorption of CO_2 by blood becomes untenable.

Believing that the colloids present in blood might very probably play an important *rôle*, it was decided to undertake an extended investigation of the influence of colloids on the absorption of gases by water, since only a very few experiments in this direction have been carried out (Geffchen).

The following results have been obtained by Mr. W. H. Harby, B.Sc., working under the direction of the Author. All determinations were made at 25°, and the solubility values represent the ratio of gas volume absorbed to the volume of the absorbing liquid:—

I.	*Solubility in water:* 0·823. Experimental error about ± 0·25 per cent.				
II.	*Colloidal ferric hydroxide*—				
	Grams of $Fe(OH)_3$ in 100 c.c. of liquid	1·36	0·68	0·34	0·136
	Solubility of CO_2	0·896	0·877	0·837	0·824
III.	*Gelatin*—				
	Grams of gelatin in 100 c.c. of liquid	5	3	1	
	Solubility of CO_2	0·848	0·834	0·826	
IV.	*Arsenious sulphide*—				
	Grams As_2S_3 in 100 c.c. of liquid . .	0·305	0·244	0·122	0·0244
	Solubility of CO_2	0·822	0·825	0·825	0·825
V.	*Silicic acid*—				
	Grams H_2SiO_3 in 100 c.c. of liquid .	0·113		0·068	
	Solubility of CO_2	0·823		0·822	
VI.	*Dextrin*—				
	Grams of dextrin in 100 c.c. of liquid .	20	10	5	1
	Solubility of CO_2	0·735	0·757	0·768	0·817
VII.	*Soluble starch*—				
	Grams of starch in 100 c.c. of liquid .	10	5	1	
	Solubility of CO_2	0·776	0·801	0·815	
VIII.	*Glycogen*—				
	Grams of glycogen in 100 c.c. of liquid	1·18	-	0·263	
	Solubility of CO_2	0·804		0·820	
IX.	*Albumen.*				
	Grams of albumen in 100 c.c. of liquid	0·5		0·75	
	Solubility of CO_2	0·822		0·822	

Experiments, still in progress, have been made with the white of egg, diluted with five times its volume of water. An increase of about 8 per cent. in the solubility of CO_2 was found. Soon, however, a precipitate began to form, and the solubility of CO_2 diminished, some of the gas which had been dissolved passing out of solution. Finally, there was an increase in the solubility of about 4 per cent.

6. *The Density of Liquids at Low Temperatures.* *By* Dr. J. TIMMERMANS.

To continue Young's experiments on the rectilinear diameter the densities of liquids from 0° C. to their melting-points have been investigated.

The thermometric method was employed, using a platinum resistance thermometer. An apparatus, which contained pure liquids at their melting-point, was devised to keep the temperature absolutely constant. The experimental error was within 1/10,000.

The following preliminary conclusions may be stated:—

1. The 'rectilinear diameter' is very slightly curved down to the melting-point.
2. The arc of the curvature corresponds to that observed by Young at higher temperatures.

7. *The Work of Two Irish Chemists, Bryan Higgins and William Higgins.* *By* Dr. A. MELDRUM.

The two Irishmen Bryan Higgins and William Higgins are known to chemists, if known at all, as, having adopted in the eighteenth century ideas which in some respects forestalled the atomic theory of the nineteenth.

Bryan Higgins (*b.* 1737, *d.* 1820) was remarkable as a teacher of chemistry, as a technical chemist, as an investigator into pure chemistry, and also by reason of his atomic speculations.

He was a pioneer of the practical teaching of chemistry, and gave instruction in the subject for some twenty-three years (1774–1796) in his School of Practical Chemistry in Greek Street, Soho, London. Towards the end of his career as a teacher he was instrumental in spreading a knowledge of the new (antiphlogistonist) system of chemistry. The 'Society for Philosophical Experiments and Conversations' met in his laboratory (1794 *et seq.*). Before this Society, which included politicians, lawyers, and physicians of high standing in London, Higgins demonstrated the experiments which formed the basis of the new chemistry.

His practical work, which is extensive, was carried out with extraordinary attention to detail. As technical chemist he did work on cements, on soap, and on glass. In the West Indies, where he went on the invitation of a committee of the Jamaica House of Assembly, he investigated the manufacture of muscovado sugar and rum (1797–1802). In pure chemistry he carried out one large research, and made a number of minor discoveries, including that of the musical note which may be produced when a jet of hydrogen burns in air.

'The Experiments and Observations concerning Acetous Acid,' &c. (1786), is an elaborate investigation into acetic acid and acetates. Higgins describes the preparation of pure acetic acid, and of the acetates of calcium, potassium, magnesium, ammonium, and lead. Having investigated the effect of heat upon these substances, he arrived at a definite conclusion regarding the constitution of acetic acid—virtually, that it consists of carbon dioxide ('fixable air') and methane ('heavy inflammable air').

Distilling ammonium acetate, he obtained acetamide. He purified it carefully by 'five sublimations,' and in a detailed account of its properties gives the melting-point as 170° F. instead of 177° F.

In the 'Philosophical Essay concerning Light' (1776) Higgins gives reasons for rejecting the emission theory of light and for adopting an undulatory theory, but on this question he afterwards changed his mind. He adapted the Newtonian atomic theory to the purposes of chemistry, and supposed that acid and alkali combine atom with atom. In this way he accounted for the fact, which he proved by an ingenious experiment, that ammonia and hydrochloric acid gases combine in single definite proportion.

William Higgins (*d.* 1825) was trained in chemistry by his uncle Bryan Higgins. He assisted Dr. Beddoes in the teaching of chemistry at Oxford (1787), and he acted as chemist to the Apothecaries' Hall of Ireland (1791–1795), and then to the Royal Dublin Society (1795–1825). He carried out experimental work on bleaching for the Irish Linen Board. A Fellow of the Royal Irish Academy, he acted as a member of its Council for many years. In 1806 he was elected to the Royal Society of London. He published three books: (1) 'A Comparative View of the Phlogistic and Antiphlogistic Theories' (1789); (2) 'An Essay on the Theory and Practice of Bleaching, wherein the Sulphuret of Lime is recommended as a Substitute for Potash' (1799); (3) 'Experiments and Observations on the Atomic Theory and Electrical Phenomena' (1814).

Having become a Lavoisierian in 1785, Higgins was the first to write against phlogiston in the English language. Written expressly in reply to Kirwan's essay on the subject, the 'Comparative View' was published in the year 1789, just when there was a revulsion of feeling in England in favour of phlogiston.

He made the important observations that at the ordinary temperature—

(1) Quicklime and dry hydrochloric acid gas do not combine (1789).
(2) Dry nitric oxide and sulphuretted hydrogen do not interact (1814).
(3) Phosphorus does not act with undiluted oxygen as it does with the oxygen of the air (1814).

Throughout the 'Comparative View' Higgins makes use of the atomic theory. He believed firmly that combination occurs in definite proportions, and he supposed that in the first place combination occurs atom with atom. The molecule of water he regarded virtually as OH.

In the case of water, sulphuretted hydrogen, and sulphur dioxide he attempted to connect the composition by volume, which he knew, with the composition in terms of atoms.

Knowing various cases of combination of two elements in more than one proportion, he continued to apply the atomic theory. He regarded sulphurous acid virtually as SO, and sulphuric acid as SO_2. He recognised five oxides of nitrogen, which he regarded as NO, NO_2, NO_3, NO_4, and NO_5. In the Wilde Lecture for 1908, on the 'Physical Aspects of the Atomic Theory,'[1] Larmor expresses the 'Daltonian principle' in the words 'a definite molecule for each substance.' This principle, which is certainly common to the various systems of chemistry of the nineteenth century, was adopted by William Higgins as early as the year 1789.

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8. *The Action of the Enzymes of Malt on Ungerminated Cereals.* *By* JULIAN L. BAKER, *F.I.C., and* H. F. E. HULTON.

In a communication recently made on the strength of wheat flours[2] we recorded experiments showing that when a flour is doughed the evolution of carbonic acid under standard conditions bears no relation to the diastatic activity as expressed in degrees Lintner. When, however, a minute quantity of malt is added to the dough the volume of gas evolved during the fermentation is increased in inverse ratio to that originally given off; and in those cases where the original gas production was low it is very largely increased.

J. S. Ford and J. M. Guthrie[3] in their recent work have shown that the filtrate obtained by digesting an aqueous suspension of flour in presence of papain is enabled to saccharify a greatly increased quantity of soluble starch. In view of this work it would appear at least probable that the increased gas production obtainable from dough by the use of malt might be due to the proteolytic enzyme known to exist in malt, which by liberating more diastase, or owing to its protection of that already present, renders more of this enzyme available for the hydrolysis of the starch in flour. Ford and Guthrie (*loc. cit.*) measured the saccharifying effect alone; but the enhanced gas production observable in dough containing a trace of malt must be due to an enzyme capable of attacking the starch of the flour itself, which, of course, is fundamentally different from soluble starch. This led us to investigate the combined action of the enzymes in barley and malt upon soluble starch and starch paste, with the hope of throwing some light upon the nature of the activities involved.

If barley, when digested with malt—a substance which contains both a starch-liquefying and proteolytic enzyme—were to yield a filtrate more diastatic in its activity than that obtainable from the barley alone, then presumably this enhanced activity of barley extract might be due to the action of the proteolyst in the malt upon the barley. The nature of this increase, if any, could be investigated by comparing its action upon soluble starch and starch paste, since liquefying diastase, if liberated, cannot be supposed to increase the amount of maltose produced from soluble starch, but would materially help the saccharification of starch paste; on the other hand, if saccharifying diastase were the one formed, then the conversion of starch paste would probably not be facilitated, but soluble starch would be further saccharified and yield more maltose.

Finally ground malt and barley were separately extracted at the rate of five grams per 100 c.c. At the same time a mixture of 2½ grams of malt and 2½ grams of barley was also digested with 100 c.c. of water. Filtrates from these three extractions were examined as regards their action upon 2 per cent. soluble starch and 2 per cent. starch paste for periods of one and two hours, at a temperature of 21°, the results being expressed as grams of maltose formed per gram of barley, malt, and mixture of the two. Precautions were taken to keep the pro-

[1] *Manchester Memoirs*, 1908, **52**, No. 10, p. 10.
[2] *J. Soc. Chem. Ind.*, 1908, **27**, 368.
[3] *J. Inst. of Brewing*, 1908, **14**, 61.

portion of maltose within the limits of Kjeldahl's 'Law of Proportionality.' The following results were obtained:—

—	Soluble starch. Grams of maltose formed		Starch paste. Grams of maltose formed	
	1 hour	2 hours	1 hour	2 hours
Malt	3·95	6·66	3·55	6·27
Barley	1·03	1·53	0·92	1·57
Mixture as found	2·43	4·27	2·43	4·44
Calculated mean	2·49	4·095	2·235	3·92
Per cent. increase	0	4·2	8·5	13·0

The order of these results was several times confirmed, and in some cases larger percentage increases were obtained when acting on starch paste with the filtrate from the mixed barley and malt. The experiment recorded above makes it evident that the increased activity of the filtrate on the mixture is making itself felt principally in the direction of the hydrolysis of the starch paste, which is evidence that if an enzyme has been liberated it is one that facilitates liquefaction of starch to a far greater degree than saccharification of already soluble starch.

It is, of course, possible that in the filtrate from the mixture of barley and malt the malt portion may have contributed liquefying diastase in sufficient quantity not only for the liquefaction of the starch paste—it is itself saccharifying—but sufficient also for the liquefaction of more than this amount, which would then be available for attack by the saccharifying diastase of the barley, and thus the mean of their actions would appear in excess of the theoretical amount. It is obvious that if this is the case we should get the enhanced effect by mixing the filtrates of the separately extracted malt and barley in equal proportions and carrying out a conversion with the mixture. When this is done, however, the maltose formed is the exact mean of that obtained from the two solutions used separately.

These experiments, so far as they go, show that there is an undoubted increase in the diastatic activity of barley when digested in the presence of the enzymes of malt. This increased activity, whether due to the presence of a proteolyst or not, is exercised mainly in the direction of the liberation of starch-liquefying enzyme.

We are continuing this investigation, as we believe it may be the means of throwing further light upon some of the processes associated with germination.

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9. *The Preparation of Pure Maltose.*
By Julian L. Baker, *F.I.C.*, *and* F. E. Day.

In a paper on the Action of Ungerminated Barley Diastase on Starch [1] one of us showed that the sole products of the action of barley diastase on starch paste or soluble starch were maltose, about 60 per cent., and α-amylodextrin. The dextrins accompanying starch conversions made with malt diastase are soluble in alcohol, and it is by no means an easy matter to isolate the maltose in a state of purity. In starch conversions made with barley diastase α-amylodextrin can be easily separated from the maltose by one precipitation with alcohol, and this constitutes a convenient method for isolating pure maltose. The conversion is carried out by preparing a quantity of a 3 per cent. starch paste or a 3 per cent. solution of soluble starch and adding precipitated barley diastase, prepared according to Lintner's directions,[2] in such proportion that for every gram of starch the enzyme from 1 gram of barley is present. The hydrolysis of the starch is conducted at a temperature of 50° C. for five or six hours, and allowed to run on for several hours in the cold. The conversion is evaporated to a thin syrup and poured into so much

[1] *Chem. Soc. Trans.*, 1902, **81**, 1177. [2] *J. Prak. Chem.*, 1886 (ii.), **34**, 378.

cold alcohol (95 per cent. by weight) that the resulting strength is about 80 per cent. The α-amylodextrin is removed by filtration and the alcohol from the filtrate by distillation. The maltose syrup may be seeded with a small quantity of pure maltose and a little alcohol added. Usually in the course of a few hours a solid magma of practically pure maltose is obtained. This may be further purified by triturating the sugar with strong alcohol, filtering, dissolving in a very small quantity of water, and pouring into boiling 95 per cent. alcohol, again filtering, and crystallising the maltose from the filtrate. Prepared under these conditions, maltose separated in well-defined and relatively large plates mixed with irregular crystalline masses.

When analysed it had a specific rotatory power $(\alpha)_{D\,3\cdot 93\,\text{abs.}} = 137^\circ\cdot 1$, and a reducing power, determined under the conditions described by Brown and Millar, 102·9. The osazone, which melted at 195°, consisted entirely of characteristic broad prisms resembling ribbons in the microscopic field. The stellate aggregates of crystals, which are always present in the osazone from maltose prepared by the action of malt diastase on starch, were entirely absent. On acetylation the characteristic octacetyl maltose was obtained.

Since the microscopic appearance of the maltose suggested the possibility of a mixture, a large quantity of the sugar was collected and carefully fractionated by dissolving in water and collecting successive crops of crystals. The fractions had specific rotatory powers of $(\alpha)_D = 137\cdot 5$ to $138\cdot 4$ abs. and reducing powers of 101·0 to 103·0 (calculated from Brown and Millar's Tables). The residential mother liquor also had the constants $(\alpha)_D = 3\cdot 93$ abs. $+ 137\cdot 4$ and $R = 99\cdot 4$. Maltose of this degree of purity separates with remarkable ease from strong aqueous solutions.

It will be noted that the reducing powers are all slightly higher than the values recorded by Brown and Millar. We believe this to be due to the great difficulty of preparing pure maltose by the action of malt diastase on starch.

Joint Discussion with Sections A and G on Gaseous Explosions.

MONDAY, SEPTEMBER 7.

The following Papers and Report were read:—

1. *The Inactive Gases. By* Sir WILLIAM RAMSAY, *K.C.B., F.R.S.*

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2. *Lithium in Radio-active Minerals.* *By* Professor W. N. HARTLEY, *D.Sc., F.R.S.*

The question as to whether lithium is or is not a widely occurring element, and whether it is found associated with any other element, more particularly with copper than with the alkalis or the alkaline earths, arises from the assumed transmutation of copper contained in solutions, into lithium, neon, and possibly other substances.

It has been stated by Sir William Ramsay:—[1]

'As sodium and potassium are much more widely distributed than lithium, it is more likely that they are the chief products from copper, and that some modifying circumstance has determined the formation of a trace of lithium. . . . Lithium was mentioned because it is an unlikely constituent of dust, glass, copper, &c., which were tested specially to prove its absence.'

[1] *Nature*, March 5, 1908 p. 412.

There are two statements here which, according to my experience, appear to require modification. That potassium and sodium are more abundantly distributed than lithium is true, but that these are more widely distributed is not strictly correct; nor can it be accepted as unquestionable that lithium is an unlikely constituent of dust, glass, copper, &c. Evidence to the contrary is based upon facts divided into three categories—first, those derived from the qualitative spectroscopic analysis of common ores and minerals usually associated with the alkali metals; secondly, analysis of the crude salts of the alkalis, such as the Stassfurth minerals and nitrates from Chile and Bengal, show that they contain lithium and rubidium, with not unfrequently cœsium. Facts belonging to the third category are derived from experimental evidence, which is both quantitative and spectrographic, the source of the spectra being the oxyhydrogen flame. When half a gramme of material yields a photograph of the spectrum of lithium on which the four chief lines are visible—namely, $\lambda\,\lambda$ 6708, 4603·07, 4132·93, and 3232·82—there cannot be less than 0·0089 gramme of lithium present. When only the lines 6708·0 and 4603·07 are visible, the quantity is not less or more than 0·0041 gramme.

When only the red line is photographed the quantity is not more than 0·002 gramme, and with half this quantity the line ceases to be photographed. It follows, therefore, that from the evidence afforded by the number of plates on which this line appears there could scarcely be less lithium in the 0·5 gramme of material analysed than 0·2 per cent.

Further results have been obtained with several other metallic compounds, but the sensitiveness of the flame reaction varies extraordinarily with the spectra of different elements.

Mr. Ramage and I found in a hundred and seventy common ores and minerals potassium and sodium, and with these common elements rubidium and lithium were very generally associated. Thus, of sixty-two iron ores, rubidium was found in sixty-one. In sixteen red hæmatites, massive minerals of the purest type, rubidium was contained in four. Where potassium and rubidium occurred lithium was invariably found. It was found in limestones, in dust, in the Bessemer flame, in ordinary pipeclay, tobacco pipes, and a great variety of siliceous minerals, such as the Dublin granites; in Donegal kyanite, which contains 98 per cent. of aluminium silicate; and in asbestos. It was found in dust which fell from the clouds, in volcanic dust, in soot, in flue-dust from chemical works, and in that from copper smelting and refining works. This last material contained lithium, sodium, potassium, rubidium, and cœsium; copper, silver calcium, strontium, aluminium, gallium, indium, thallium, iron, nickel, cobalt, manganese, chromium, lead, zinc, cadmium, and tin. Upon such evidence as this it is impossible to corroborate the statement that potassium is a more widely distributed element than lithium, or that lithium is an unlikely constituent of dust, glass, copper, &c.

3. *The Liquefaction of Helium.* *By* Dr. Kammerlingh Onnes.

4. *Anticipations and Experiments on the Liquefaction of Helium.* *By* Sir James Dewar, *F.R.S.*

5. *A Demonstration on the Rapid Electroanalytical Separation of Metals.* *By* Dr. Henry J. S. Sand.

In the process of electroanalysis to be shown the principle of very vigorous stirring of the electrolyte has been combined with that of keeping the potential of the cathode under control by means of an auxiliary electrode. It has thus been possible very largely to extend the scope of electroanalytical methods. The following metals have hitherto been studied. First the metals of the silver and copper groups and zinc, *i.e.*, silver, mercury, copper, bismuth, lead, cadmium, and zinc. These metals have all been deposited singly, separated from each other and also separated when all present in the same solution. In the last-named case the quantity of each metal taken varied between 0·10 and 0·15 gram, and the time for the deposition of each between about ten and fifteen minutes.[1] Secondly, new methods have been elaborated for the determination and separation from each other of antimony and tin. A considerable number of determinations have been carried out in which the metals taken in varying ratios weighed together approximately one gram. The time for the deposition of the antimony was usually about twenty minutes, that for the tin about eighty minutes. Lastly, the possibility of securing a purely electroanalytical method for the analysis of an alloy consisting of copper, antimony, lead and tin has been examined, and all the separations required for such an analysis have been carried out.

6. *Studies on the Electro-deposition of Metals.* *By* W. E. Hughes *and* Dr. F. M. Perkin.

7. *Transparent Silver and other Metallic Films.* *By* Professor Thomas Turner, *M.Sc.*

Thin gold-leaf, when mounted on glass, becomes transparent when heated to about 550° C. The light transmitted is white, and the effect does not depend upon the supporting material or the gaseous atmosphere.

Thin silver-leaf becomes transparent if heated in air or oxygen. The light transmitted is white, and the effect is not produced *in vacuo* or in a reducing atmosphere. Though oxygen is necessary it is not appreciably absorbed, and the effect is only noticed with thin sheets. Silver $\frac{1}{10000}$ of an inch in thickness is too thick to show the effect.

Thin sheet-copper when heated in air or oxygen to about 200° C. gradually passes into a transparent substance which transmits yellow-green light quite freely. With further heating the colour darkens until at length it becomes black. No effect is produced in a reducing atmosphere.

Thin sheet-aluminium does not become transparent when heated. For further particulars the original paper may be consulted.[2]

8. *Report on Wave-length Tables of the Spectra of the Elements.* See Reports, p. 119.

TUESDAY, SEPTEMBER 8.

The following Papers and Reports were then read:—

1. *Discussion on Problems of Fermentation.*

(i) *The Factors which influence the Rate of Alcoholic Fermentation.* *By* Arthur Slator, *Ph.D.*, *D.Sc.*

The transformation of glucose into alcohol and carbon-dioxide by the action of yeast is probably not a single chemical reaction but a series of reactions. If one reaction of the series proceeds relatively much more slowly than the others, then the velocity of the transformation is determined by the rate of this slow reaction.

[1] *Trans. Chem. Soc.*, 1907, **91**, 373. [2] *Proc. Royal Soc.*, May 1908.

Evidence was brought forward to show that the initial rate of fermentation by living yeast is controlled almost completely by one single reaction. By considering only these initial velocities certain disturbing secondary reactions are eliminated, for change of conditions, which are usually considered to influence the rate of fermentation, have no effect on these initial velocities. The simple laws governing the rate are evidence in favour of considering one reaction to have the control of the velocity.

The rate of fermentation is exactly proportional to the amount of yeast present. The rate of fermentation of the four fermentable hexoses (glucose, fructose, galactose, and mannose) is almost independent of the concentration of the sugar. Glucose and fructose are fermented at approximately equal rates. Yeasts which ferment glucose do not always possess the property of fermenting galactose, and this sugar is fermented only by yeasts which have been grown in the presence of galactose. The fermentation of mannose is similar to that of glucose, but the rates of the two reactions are not equal. The enzyme which ferments mannose seems to be more sensitive to heat than the one which ferments glucose. The influence of temperature on these reactions is almost the same in the case of glucose, fructose, and mannose, but rather less in the case of galactose. These results are most easily brought into accord on the assumption that the enzyme combines with the sugar. Glucose and fructose form the same compound; galactose and mannose form different compounds. It is possible that there exist three different enzymes: glucozymase, which ferments glucose and fructose; galactozymase, which ferments galactose; and mannozymase, which ferments mannose. It is probable that no compound has yet been isolated which can be considered intermediate in alcoholic fermentation. The suggestion that lactic acid is such a compound is of special interest, and has attracted much attention. Lactic acid does not ferment, or ferments only very slowly and incompletely. This is the chief objection to the hypothesis. An intermediate compound must be at least as reactive as the original reagent. The suggestion that lactic acid is liberated in a 'nascent state' is considered unlikely, for in constructing the mechanism of other similar chemical reactions such suppositions have not been found necessary.

Fermentation by yeast-juice differs in many respects from that by living yeast. It is probable that the mechanism of the reaction is the same in each case; but the relative rates of the different steps in the two processes are different. The experiments show that there is an essential step in fermentation in which phosphates in some form or another play a part. This reaction proceeds too rapidly in fermentation by living yeast to have any controlling influence on the velocity; but in the fermentation by yeast-juice it proceeds relatively more slowly and influences the rate.

The method of investigating complicated reactions by considering only initial velocities has the advantage that disturbing side reactions are to a large extent eliminated. The method can probably be applied with advantage to other enzyme processes.

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2. *The Selective Permeability of certain Seeds.* *By* Professor ADRIAN BROWN.

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3. *The Production of Ammonia from Atmospheric Nitrogen by means of Peat.* *By* H. C. WOLTERECK, *Ph.D.*

Attempts to utilise the nitrogen contents of peat have been made during the last sixty years, but the yield of ammonia obtained by the various processes which have been tried shows that only about one-third of the nitrogen can be thus recovered. Starting from an observation that a mixture of nitrogen and hydrogen passed over reduced iron at a low heat always produced ammonia for some time, the Author made further experiments on these lines, and found that the presence of oxygen and water was of importance This led to the gradual reduction of the quantity of hydrogen, and finally to its complete omission; but the periodical necessity of reducing the iron used for the purposes of moist oxidation led him to employ some carbonaceous material (coke, coal, charcoal, &c.), for this purpose.

Finally peat was found to give the most satisfactory and rapid results, and even when it contained up to 80 per cent. of water it could be utilised advantageously.

In the meantime experiments were made to prove the co-operation of atmospheric nitrogen. Sugar carbon absolutely free from nitrogen was treated by the process and produced an average of 1 per cent. ammonia on the carbon consumed.

The large plant erected at Carnlough, co. Antrim, has finally confirmed the working and results of the process on a commercial scale.

4. *Discussion on Peat.*

5. *Report on the Study of Hydro-aromatic Substances.*—See Reports, p. 221.

6. *Report on the Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives.*—See Reports, p. 115.

7. *Interim Report on the Study of Isomorphous Sulphonic Derivatives of Benzene.*

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION.—Professor JOHN JOLY, Sc.D., F.R.S.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address:—

URANIUM AND GEOLOGY.

INTRODUCTION.

IN our day but little time elapses between the discovery and its application. Our starting-point is as recent as the year 1903, when Paul Curie and Laborde showed experimentally that radium steadily maintains its temperature above its surroundings. As in the case of many other momentous discoveries, prediction and even calculation had preceded it. Rutherford and McClung, two years before the date of the experiment, had calculated the heat equivalent of the ionisation effected by uranium, radium, and thorium. Even at this date (1903) there was much to go upon, and ideas as to the cosmic influence of radio-activity were not slow in spreading.[1]

I am sure that but few among those whom I am addressing have seen a thermometer rising under the influence of a few centigrams of a radium salt; but for those who pay due respect to the principles of thermodynamics, the mere fact that at any moment the gold leaves of the electroscope may be set in motion by a trace of radium, or, better still, the perpetual motion of Strutt's 'radium clock,' is all that is required as demonstration of the ceaseless outflow of energy attending the events proceeding within the atomic systems.

Although the term 'ceaseless' is justified in comparison with our own span of existence, the radium clock will in point of fact run down, and the heat outflow gradually diminish. Next year there will be less energy forthcoming to drive the clock, and less heat given off by the radium by about the one three-thousandth part of what now are evolved. As geologists accustomed to deal with millions of years, we must conclude that these actions, so far from being ceaseless, are ephemeral indeed, and that if importance is to be ascribed to radium as a geological agent, we must seek to find if the radium now perishing off the earth is not made good by some more enduringly active substance.

That uranium is the primary source of supply cannot be regarded as a matter of inference only. The recent discovery of ionium by Boltwood serves to link uranium and radium, and explains why it was that those who sought for radium as the immediate offspring of uranium found the latter apparently unproductive, the actual relation of uranium to radium being that of grandparent. But even were we without this connected knowledge, the fact of the invariable occurrence

[1] See letters appearing in *Nature* of July 9 and September 24, 1903, from the late r. W E. Wilson and Sir George Darwin referring to radium as a solar constituent and one from the writer (October 1, 1903) on its influence as a terrestrial constituent.

in Nature of these elements, not only in association but in a quantitative relationship, can only be explained on a genetic connection between the two. This evidence, mainly due to the work of Boltwood, when examined in detail, becomes overwhelmingly convincing.

Thus it is to uranium that we look for the continuance of the supplies of radium. In it we find an all but eternal source. The fraction of this substance which decays each year, or, rather, is transformed to a lower atomic weight, is measured in tens of thousands of millionths; so that the uranium of the earth one hundred million years ago was hardly more than one per cent. greater in mass than it is to-day.

As radio-active investigations became more refined and extended, it was discovered that radium was widely diffused over the earth. The emanation of it was obtained from the atmosphere, from the soil, from caves. It was extracted from well waters. Radium was found in brick-earths, and everywhere in rocks containing the least trace of demonstrable uranium, and Rutherford calculated that a quantity of radium so minute as $4{\cdot}6 \times 10^{-14}$ grams per gram of the earth's mass would compensate for all the heat now passing out through its surface as determined by the average temperature gradients. In 1906 the Hon. R. J. Strutt, to whom geology owes so much, not only here but in other lines of advance, was able to announce, from a systematic examination of rocks and minerals from various parts of the world, that the average quantity of radium per gram was many times in excess of what Rutherford estimated as adequate to account for terrestrial heat-loss. The only inference possible was that the surface radium was not an indication of what was distributed throughout the mass of the earth, and, as you all know, Strutt suggested a world deriving its internal temperature from a radium jacket some 45 miles in thickness, the interior being free from radium.[1]

My own experimental work, begun in 1904, was laid aside till after Mr. Strutt's paper had appeared, and a valued correspondence with its distinguished author was permitted to me. This Address will be concerned with the application of my results to questions of geological dynamics.

Did time permit I would, indeed, like to dwell for a little on the practical aspect of measurements as yet so little used or understood; for the difficulties to be overcome are considerable, and the precautions to be taken many. The quantities dealt with are astoundingly minute, and to extract with completeness a total of a few billionths of a cubic millimetre of the radio-active gas—the emanation—from perhaps half a litre or more of a solution rich in dissolved substances cannot be regarded as an operation exempt from possibility of error; and errors of deficiency are accordingly frequently met with.

Special difficulties, too, arise when dealing with certain classes of rocks. For in some rocks the radium is not uniformly diffused, but is concentrated in radio-active substances. We are in these cases assailed with all the troubles which beset the assayer of gold who is at a loss to determine the average yield of a rock wherein the ore is sporadically distributed. In the case of radium determinations this difficulty may be so much the more intensified as the isolated quantities involved are the more minute and yet the more potent to affect the result of any one experiment. There is here a source of discrepancy in successive experiments upon those rocks in which, from metamorphic or other actions, a segregation of the uranium has taken place. With such rocks the divergences between successive results are often considerable, and only by multiplying the number of experiments can we hope to obtain fair indications of the average radio-activity. It is noteworthy that these variations do not, so far as my observations extend, present themselves when we deal with a recent marine sediment or with certain unaltered deposits wherein there has been no readjustment of the original fine state of subdivision, and even distribution, which attended the precipitation of the uranium in the process of sedimentation.

But the difficulties attending the estimation of radium in rocks and other

[1] *Proc. R.S.*, lxxvii. p. 472, and lxxviii. p. 150.

materials leave still a large balance of certainty—so far as the word is allowable when applied to the ever-widening views of science—upon which to base our deductions. The emanation of radium is most characteristic in behaviour; knowledge of its peculiarities enables us to distinguish its presence in the electroscope not only from the emanation of other radio-active elements, but from any accidental leakage or inductive disturbance of the instrument. The method of measurement is purely comparative. The cardinal facts upon the strength of which we associate radium with geological dynamics, its development of heat and its association with uranium, are founded in the first case directly on observation, and, in the second, on evidence so strong as to be equally convincing. Recent work on the question of the influence of conditions of extreme pressures and temperatures on the radio-active properties of radium appear to show that, as would be anticipated, the effect is small, if indeed existent. As observed by Makower and Rutherford, the small diminution noticed under very extreme conditions in the γ radiation possibly admits of explanation on indirect effects. These observations appear to leave us a free hand as regards radio-thermal effects unless when we pursue speculations into the remoter depths of the earth, and even there while they remain as a reservation, they by no means forbid us to go on.

The precise quantity of heat to which radium gives rise, or, rather, which its presence entails, cannot be said to be known to within a small percentage, for the thermal equivalent of the radio-active energy of uranium, actinium, and ionium, and of those members of the radium family which are slow in changing, has not been measured directly. Professor Rutherford has supplied me, however, with the calculated amount of the aggregate heat energy liberated per second by all these bodies. In the applications to which I will presently have to refer I take his estimate of $5{\cdot}6 \times 10^{-2}$ calories per second as the constant of heat-production attending the presence of one gram of elemental radium.

To these words of introduction I have to add the remark, perhaps obvious, that the full and ultimate analysis of the many geological questions arising out of the presence of radium in the earth's surface materials will require to be founded upon a broader basis than is afforded by even a few hundred experiments. The whole sequence of sediments has to be systematically examined; the various classes of igneous materials, more especially the successive ejecta of volcanoes, fully investigated. The conditions of entry of uranium into the oceanic deposits has to be studied, and observations on sea-water and deep-sea sediments multiplied. All this work is for the future; as yet but little has been accomplished.

The Radium in the Rocks and in the Ocean.

The fact first established by Strutt that the radium distributed through the rock materials of the earth's surface greatly exceeds any permissible estimate of its internal radio-activity has not as yet received any explanation. It might indeed be truly said that the concentration of the heaviest element known to us, (uranium) at the surface of the earth is just what we would not have expected. Yet a simple enough explanation may be at hand in the heat-producing capacity of that substance. If it was originally scattered through the earth-stuff, not in a uniform distribution but to some extent concentrated fortuitously in a manner depending on the origin of terrestrial ingredients, then these radio-active nuclei heating and expanding beyond the capacity of surrounding materials would rise to the surface of a world in which convective actions were still possible and, very conceivably, even after such conditions had ceased to be general: and in this way the surface materials would become richer than the interior. For instance, the extruded mass of the Deccan basalt would fill a sphere 36 miles in radius. Imagine such a sphere located originally somewhere deep beneath the surface of the earth surrounded by materials of like density. The ultimate excess of temperature, due to its uranium, attained at the central parts would amount to about 1000° C., or such lesser temperature as convective effects within the mass would permit. This might take some thirty million years to come about, but before so great an excess of temperature was reached the force of buoyancy developed in virtue of its thermal expansion must inevitably bring the entire mass to the surface. This reasoning would, at any rate, apply to material situated at a considerable distance inwards, and may possibly be connected with vulcanicity and other crustal disturbances observed at the surface.[1] The other view, that the addition of uranium to the earth was mainly an event subsequent to its formation in bulk, so that radio-active substances were added from without and, possibly, from a solar or cosmic source, has not the same *à priori* probability in its favour.[2]

I have in this part of my Address briefly to place before you an account of my experiments on the amounts of radium distributed in surface materials. Here, indeed, direct knowledge is attainable; but this knowledge takes us but a very few miles inwards towards the centre of the earth.

The Igneous Rocks.—The basalt of the Deccan, to which I have referred, known to cover some 200,000 square miles to a depth of from 4,000 to 6,000 feet or more, appears to be radio-active throughout. A fine series of tunnel and surface specimens sent to me by the Director of the Indian Geological Survey has enabled me to examine the radio-activity at various points. It is remarkable that the mean result does not depart much from that afforded by a long series of experiments on North of Ireland basalt and on the basalt of Greenland.

Again, the granites and syenites—and those of Mourne, Aberdeen, Leinster, Plauen, Finsteraarhorn have been examined—while variable, yet approximate to the same mean result.

In the Simplon and St. Gothard tunnels igneous rocks have been penetrated at considerable depth beneath the surface. The greatest true depth is attained, I think, in the central St. Gothard massif. It is remarkable, and may be significant, that in these rocks I have reached the lowest radio-activities I have met—down to almost one billionth of a gram of radium per gram; although the general mean of the St. Gothard igneous rocks, owing to the high radio-activity of the Finsteraar granite at the north end of the tunnel, is not exceptionally low. Radio-active minerals seem common in the Simplon rocks, involving considerable variations in successive experiments. Some of the highest results are omitted in the mean given below, but as it is difficult to know what to allow for purely sporadic radium the mean is not very certain. In the case of a specially high result I asked Professor Emil Werner to determine the uranium: my result was confirmed. My list of mean results on igneous rocks up to the present is the following:—

Basalts (14)	5·0[3]	Lewisian Gneiss (3)	5·7
Granites (6)	4·1	Simplon (32)	7·6
Syenites (1)	6·8	St. Gothard (32)	5·1

The general mean is 6·1.

From the igneous rocks have originated the sediments after a toll of dissolved substances has been paid to the ocean. It does not of course follow necessarily that the percentage of radium, or more correctly of uranium, in the sedimentary rocks should be less than in the igneous. The residual materials might keep the original percentage of the parent rock, or even improve upon it. There are reasons for believing, however, that there would be a diminution.

Those sedimentary rocks which have been derived from materials formerly in solution offer a different problem. In their case there is little or none of the original materials carried into the secondary rock, and the radio-activity will depend mainly upon how far uranium is precipitated or abstracted with the rock-making substances. In other words, upon how far the waters of the ocean will restore to the rocks what it has borrowed from them.

This brings me to consider the condition of the ocean as preparatory to quoting experiments on the sediments.

[1] See Appendix A. [2] *Nature*, lxxv. p. 294.

[3] This number is to be multiplied by 10^{-12}, and represents billionths of a gram of radium per gram of material investigated. Throughout the rest of my Address this understanding holds, unless where a different meaning is specified. The numbers in parentheses signify the number of different specimens investigated.

The Ocean and its Sediments.—The waters of the ocean, covering five-sevenths of the earth's surface to a mean depth of 3·8 kilometres, represent the most abundant surface material open to our investigation. As the mean of a very large number of experiments upon twenty-two different samples of sea-water from various widely separated parts of the ocean, I obtain a mean of $0·016 \times 10^{-12}$ gram per cubic centimetre. There is considerable variability. Taking the mass of the ocean as $1·458 \times 10^{18}$ tonnes, there must be about 20×10^{9} grams (20,000 tons) of radium in its waters.

The experiments which I have been able to make on deep-sea deposits, thanks mainly to the kind co-operation of Sir John Murray, apply to ten different materials of typical character.

The results are so consistent as to lead me to believe that although so few in number they cannot be far wrong in their general teaching.

The means are:—

	Radium	Extension: Millions of Square Miles.
Globigerina Ooze .	7·2	49·5
Radiolarian Ooze .	36·7	2·5
Red Clay . . .	33·3	51·5

Diatom Oozes have not yet been examined.

It is apparent from these results that the more slowly collecting sediments are those of highest radio-activity, as if the organic materials raining downwards from the surface of the ocean carried everywhere to the depths uranium and radium abstracted from the waters; but in those regions where the conditions were inimical to the preservation of the associated calcareous tests, there was the less dilution of the radio-active substances accumulating beneath. The next table shows that radio-activity and the percentage of calcareous matter in these deposits stand in an inverse relation:—

—	Calcium Carbonate per cent.	Radium
Globigerina Ooze, 'Chall.' 338 . .	92·24	6·7
Globigerina Ooze, ,, 296 . .	64·34	7·4
Red Clay . . ,, 5 . .	12·00	15·4
Red Clay . . ,, 276 . .	28·28	52·6
Radiolarian Ooze ,, 272 . .	10·19	22·8
Radiolarian Ooze ,, 274 . .	3·89	50·3

The percentages of calcium carbonate are from the Report of the 'Challenger' Expedition. The Red Clay in the table, which reads as an apparent exception, is probably a case of recent change in the character of the deposit, for the evidence of manganese nodules and sharks' teeth brought up with this clay is conclusive as to the slow rate of its collection. Readers of Sir John Murray's and Professor Renard's report will remember many cases where recent change in the character of a deposit is to be inferred.

A point of much importance in connection with our views on oceanic radio-activity is that of the presence in the waters and in the deposits of the parent radio-active substance, uranium. The evidence that the full equivalent amount of uranium is present is, I believe, conclusive.

In the first place, to so vast a reservoir as the ocean the rivers cannot be supposed to supply the radium sufficiently fast to make good the decay. In a very few thousand years, in the absence of uranium, the rivers must necessarily renew almost the entire amount of radium present. I have made examination of the water of one great river only—the Nile. The quantity of radium detected was $0·0042 \times 10^{-12}$ per cubic centimetre. That is less than the oceanic amount. In short, it is evident that the uranium must accumulate year by year in the oceanic reservoir, like other substances brought in by the rivers, and that the present state of the waters is the result of such actions prolonged over geological time.

While this reasoning is conclusive as regards the waters of the ocean, it does not assure us that the sediments accumulating in their depths are throughout as radio-active as their surface parts would indicate. There might be a precipitation of radium unattended by uranium, in which case their deeper parts would not be radio-active.

Against this possibility there is the evidence of such true deep-sea deposits as were formed in past times and to-day still preserve their radio-activity. For instance, the chalk, which, considering that it was undoubtedly a very rapidly formed deposit, exhibits a radio-activity quite comparable with that of the Globigerina Oozes, deposits which it most nearly resembles. In this deposit, clearly, the uranium must have collected along with the calcareous materials. We can with security argue that the similar oozes collected to-day must likewise contain uranium. In the case of the Red Clays we have the direct determination of the uranium which Professor Emil Werner was so good as to make at my request. Considering the difficulties attending its separation, the result must be taken as supporting the view that here, too, the radium is renewed from the uranium. Regarding the efforts of other observers to detect uranium in such deposits, it is noteworthy that without the guidance of the radium, enabling specially rich materials to be selected for analysis, the success of the investigation must have been doubtful. The material used was a Red Clay with the relatively large quantity of 54·4 billionths of a gram per gram. In a few grams of this Werner obtained up to seven-twelfths of the total theoretic amount, and of course the separation of the uranium is not likely to have been complete.

It might be thought a hopeless task to offer any estimate of the total bulk of the sub-oceanic deposits, and from this to arrive at some idea of the quantity of radium therein contained. Nevertheless, such an estimate is not only possible but is based on deductions which possess considerable security. As a major limit I believe the estimate of the total mass of deposit is unassailable, and such deductions as might be applied will still leave it an approximation to the truth.

The elements of the problem are simple enough; we know that the sedimentary rocks have been derived from the igneous, some 30 per cent. of the latter entering into solution in the process of conversion. Some of the soluble constituents, owing to their great solubility, have remained in solution since they entered the ocean.[1] These are the salts of sodium. An estimate of the amount of these salts in the ocean gives us a clue to the total amount of rock substance which has contributed to oceanic salts and oceanic deposits since the inception of the oceans. Some years ago I deduced on this basis that the igneous rocks which are parent to the sodium in the sea must have amounted to about 91×10^{16} tons.[2] This figure in no way involves the rate of supply by the rivers, or our estimate of geological time. It only involves the quantity of sodium now in the ocean—a fairly well-known factor—and the loss of this element, which occurs when average igneous rocks are degraded into sedimentary rocks—a factor also fairly well known. Mr. F. W. Clark, to whom geological science is indebted for so much exact investigation, has recently repeated this calculation, using data deduced anew by himself, and arrives at the result that the bulk of the parent igneous rock was $84{\cdot}3 \times 10^6$ cubic miles.[3] On a specific gravity of 2·6 my estimate in tons gives nearly the same result: 84×10^6 cubic miles.

Now about one-third part of this parent rock goes into solution when breaking up into a detrital sediment. The limestones upon the land are part of what was once so brought into solution. Having made deduction of these former marine deposits (and I here avail myself of Van Hise's and Clark's estimates of the total amount of the sedimentaries and the fraction of these which are calcareous),[4] and, allowing for the quantity remaining in solution in the ocean, the result leaves us with the approximation of twenty million cubic miles of matter once in solution, and now for the greater part existing as precipitated or abstracted deposits at the bottom of the ocean. We are to distribute this quantity over its

[1] *Trans. Royal Dublin Soc.*, vol. vii. ser. ii. p. 23 *et seq.*
[2] *Ibid.*, p. 46.
[3] *The Data of Geochemistry.* By F. W. Clark, p. 29.
[4] *Ibid.*, p. 31.

floor. If the rate of collection had been uniform in every part of the ocean throughout geological time, a depth of about one-seventh of a mile (240 metres) of deposit would cover the ocean bed.

While, I believe, we can place considerable reliance on this approximation, we are less sure when we attempt an estimate of its mean radio-activity. If we assume for it an average radio-activity similar to that of Globigerina Ooze, we find that the quantity of radium involved must be considerably over a million tons. Apart from the value which such estimates possess as presenting us with a perspective view of the great phenomena we are dealing with, it will now be seen that it supports the finding of the experiments on sedimentary rocks, and leads us to anticipate a real difference in the radio-activity of the two classes of material.

The Sedimentary Rocks.—The radium content f those of detrital character is indicated in the following sandstones, slates, and shales:—

Shales, sandstones, grits (10)	4·4
Slates (Cambrian, Devonian)	4·7
Mud from Amazon	3·2

Some of the above are from deep borings in Carboniferous rocks (the Balfour and Burnlip bores),[1] and from their nature, where not actually of fresh-water origin, can owe little to oceanic radio-activity. Many of the following belong to the class of precipitates, and therefore owe their uranium wholly or in part to oceanic source:—

Marsupites chalk	4·2
Green sandstone	4·9
Green sand (dredged)	4·5
Limestones and dolomites [Trenton, Carboniferous, Zechstein, Lias, Solenhofen (7)]	4·1
Keuper gypsum	6·9
Coral rock, Funafuti bore (4)[2]	1·7
Trias-Jura sediments, Simplon: 17 rocks of various characters	6·9
Mesozoic sediments, St. Gothard: 19 rocks of various characters	4·2

The general mean on sixty-two rocks is 4·7.

Making some allowance for uncertainties in dealing with the Simplon rocks, I think the experiments may be taken as pointing to the result:—

Igneous rocks from 5 to 6.

Sedimentary rocks from 4 to 5.

If our estimate of oceanic radium be applied to the account of the sedimentary rocks in a manner which will be understood from what I have already endeavoured to convey, there will be found to exist a fair degree of harmony between the great quantities which we have found to be in the sediments of the ocean and the impoverishment of the sediments which the experiments appear to indicate.

In all these results fresh and unweathered material has been used. The sand of the Arabian desert gave me but 0·4. Similarly low results have been found by others for soils and such materials. These are not to be included when we seek the radio-activity of the rocks.

As regards generally my experiments on the radium-content of the rocks, I cannot say with confidence that there is anything to indicate a definite falling off in radio-activity in the more deeply seated materials I have dealt with. The central St. Gothard and certain parts of the Deccan have given results in favour of such a decrease. On the other hand, as will be seen later, the granite at the north end of the St. Gothard and the primitive gneiss of the Simplon show no diminution. According to the view I have put forward above as to the origin of the surface richness in radium it is I think to be expected that, while the richest materials would probably rise most nearly to the surface, there might be considerable variability in the radio-activity of the deeper parts of the upper crust.

[1] For these rocks, and for much other valuable material, I have to thank Mr. D. Tate, of the Scottish Geological Survey.

[2] For these I have to thank the Trustees of the British Museum and Mr. A. Smith Woodward, F.R.S.

Uranium and the Internal Heat of the Earth.

While forced to deny of the earth's interior any such richness in radium as prevails near the surface, the inference that uranium exists yet in small quantities far down in the materials of the globe is highly probable. This view is supported by the presence of radium in meteoric substances and by its very probable presence in the sun—that greatest of meteorites. True, the radio-thermal theory cannot be supposed to account for any great part of solar heat unless we are prepared to believe that a very large percentage of uranium can be present in the sun, and yet yield but feeble spectroscopic evidence of its existence. Taken all together, the case stands thus as regards the earth. We are assured of radium as a widely distributed surface material, and to such depths as we can penetrate. By inference from the presence of radium in meteoric substances and its very probable presence in the sun, from which the whole of terrestrial stuff probably originated, as well as by the inherent likelihood that every element at the surface is in some measure distributed throughout the entire mass we arrive at the conclusion that radium is indeed a universal terrestrial constituent.

The dependent question then confronts us—Are we living on a world heated throughout by radio-thermal actions? This question—one of the most interesting which has originated in the discovery that internal atomic changes may prove a source of heat—can only be answered (if it can be answered) by the facts of geological science.

I will not stop to discuss the evidence for and against a highly heated interior of the earth. I assume this heated interior the obvious and natural interpretation of a large class of geological phenomena, and pass on to consider certain limitations to our knowledge which have to be recognised before we are in a position to enter on the somewhat treacherous ground of hypotheses.

In the first place, we appear debarred from assuming that the surface and central interior of the earth are in thermal connection, for it seems certain that, since the remote period when (probable) convective effects became arrested by reason of increasing viscosity, the thermal relations of the surface and interior have become dependent solely on conductivity. From this it follows if the state of matter in the interior is such as Lord Kelvin assumed—that is, that the conductivity and specific heat may be inferred from the qualities of the surface materials—we have remained in thermal isolation from the great bulk of the interior for hundreds of millions of years, and perhaps even for more than a thousand million of years. Assuming a diffusivity similar to that of surface rocks, and starting with a temperature of 7000° F., Kelvin found that after 1000 million years of cooling there would be no sensible change at a depth from the surface greater than 568 miles. In short, even if this great period—far beyond our estimates of geological time—has elapsed since the *consistentior status,* the cooling surface has as yet borrowed heat from only half the bulk of the earth.

It is possible, on the other hand, that the conductivity increases inwards, as Professor Perry has contended; and if the central parts are more largely metallic, this increase may be considerable. But we find ourselves here in the regions of the unknown.

With this limitation to our knowledge, the province of geothermal speculation is a somewhat disheartening one. Thus if with Rutherford, who first gave us a quantitative estimate of the kind, we say that such and such a quantity of radium per gram of the earth's mass would serve to account for the $2{\cdot}6 \times 10^{20}$ calories which, according to the surface gradients, the earth is losing per annum, we cannot be taken as advancing a theory of radio-active heating, but only a significant quantitative estimate. For, in fact, the heat emitted by radium in the interior may never have reached the surface since the convective conditions came to an end.

And here, depending upon the physical limitations to our knowledge of the earth's interior, a possibility has to be faced. That uranium is entirely absent from the interior is, as I have said, in the highest degree unlikely. If it is present, then the central parts of the earth are rising in temperature This view, that the central interior is rising in temperature, is difficult to dispose of, although we can adduce the evidence of certain surface-phenomena to show that the rise in temperature during geological time must be small or its effects in some manner kept under control. In a word, whether we assume that the whole heat-loss of the earth is now being made good by radio-active heating or not, we find, on any probable value of the conductivity, a central core almost protected from loss by the immense mass of heated material interposed between it and the surface, and within this core very probably a continuous source of heat. It is hard to set aside any of the premisses of this argument.[1]

We naturally ask, Whither does the conclusion lead us? We can take comfort in a possible innocuous outcome. The uranium itself, however slowly its energy is given up, is not everlasting. The decay of the parent substance is continually reducing the amount of heat which each year may be added to the earth's central materials. And the result may be that the accumulated heat will ultimately pass out at the surface by conductivity, during remote future times, and no physical disturbance result.

The second limitation to our hypotheses arises from this transformation and gradual disappearance of the uranium. And this limitation seems as destructive of definite geothermal theories as the first. To understand its significance requires a little consideration. The fraction of uranium decaying each year is vanishingly small, about the ten thousand-millionth part; but if the temperature of the earth is maintained by uranium and consequently its decay involves the fall in temperature of the whole earth, the quantity of heat escaping at the surface attendant on the minute decrement would be enormous. An analogy may help to make this clear. Consider the case of a boiler maintained at a particular temperature by a furnace within. Let the combustion diminish and the furnace temperature fall a little. The whole mass of the boiler and its contents follow the downward movement of temperature, heat of capacity escaping at the surface. An observer, only noting the outflow of radiated heat and unable to observe the minute drop of temperature, would probably ascribe to the continued action of the furnace, heat which, although derived from it in the past, should no longer be regarded as indicating the heating value of the combustion. Magnify the boiler to terrestrial dimensions: the minutest fall in temperature of the entire mass involves immense quantities of heat passing out at the surface, which no longer indicate the sustaining radio-thermal actions within.

It is easy to see the nature of the difficulties in which we thus become involved. In fact, the heat escaping from the earth is not a measure of the radium in the earth, but necessarily includes, and for a great part may possibly be referred to, the falling temperature, which the decay of the uranium involves. If we take λ (the fraction of uranium transforming each year) as approximately 10^{-10} and assume for the general mass of the earth a temperature of $1500°$, a specific heat of $0{\cdot}2$, and, taking 6×10^{27} as its mass in grams, we have, on multiplying these values together, a loss in calories per annum of $1{\cdot}8 \times 10^{20}$. This by hypothesis escapes at the surface. But the surface loss, as based on earth-gradients of temperature, is but $2{\cdot}6 \times 10^{20}$ calories. We are left with $0{\cdot}8 \times 10^{20}$ calories as a measure of the radium present. On this allowance our theories, in whatever form, must be shaped. Nor does it appear as if relief from this restriction can be obtained in any other way than by denying to the interior parts of the earth the requisite high thermal conductivity. Taking refuge in this, we are however at once confronted with the possibility of internal stores of radium of which we know nothing, save that they cannot, probably, be very great in amount. In short, I believe it will be admitted on full examination of this question that, while we very probably are isolated thermally from a considerable part of the earth's interior, the decay of the uranium must introduce a large subtractive correction upon our estimates of the limiting amounts of radium which might be present in the earth.

But, finally, is there in all these difficulties sufficient to lead us to reject the view that the present loss of earth-heat may be nearly or quite supplied by radium,

[1] Professor H. A. Wilson has made a suggestive estimate of the thermal effects of radium enclosed in the central parts of the earth (*Nature*, February 20 1908).

and the future cooling of the earth controlled mainly by decay of the uranium? I do not think there are any good grounds for rejecting this view. Observe, it is the condition towards which every planetary body and every solar body containing stores of uranium must tend; and apparently must attain when the rate of loss of initial stores of heat, diminishing as the body grows colder, finally arrives at equilibrium with the radio-thermal supplies. This final state appears inevitable in every case unless the radio-active materials are so subordinate that they entirely perish before the original store of heat is exhausted.

Now, judging from the surface richness in radium of the earth and the present loss of terrestrial heat, it does not seem reasonable to assign a subordinate influence to radio-thermal actions; and it appears not improbable that the earth has attained, or nearly attained, this final stage of cooling.

How, then, may we suppose the existing thermal state maintained? A uniformly radio-active surface layer possessing a basal temperature in accordance with the requirements of geology is, I believe, not realisable on any probable estimate of the allowable radium, or on any concentration of it which my own experiments on igneous rocks would justify.

But we may take refuge in a less definite statement, and assume a distribution by means of which the existing thermal state of the crust may be maintained. A specially rich surface layer we must recognise, but this need be no more than a very few miles deep; after which the balance of the radium may be supposed distributed to any depth with which we are thermally connected. Below that our knowledge is indefinite. The heat outflow at the surface is in part from the surface radium, in part due to the cooling arising from the diminishing amount of uranium, in part from the deep-seated radium. In this manner the isogeotherms are kept in their places, and a state is maintained which is in equilibrium with the thermal factors involved, but which cannot be considered steady, using the word in a strictly accurate sense, in view of the decay of the uranium.

While the existing thermal state may, I think, thus be maintained by radio-active heating and radio-active decay, we find ourselves in considerable difficulties if we extend this view into the past and assume that the same could be said of any previous stage of the earth's history. If the heat emitted by the earth, when the surface was at melting temperature, was in a state of equilibrium with the radio-active supplies, then, at that date, there must have been many thousands of times the present amount of uranium on the earth, and the period of the *consistentior status* must be put back by thousands of millions of years. Apart from hopeless contradiction with every geological indication as to the age of the earth, difficulties in solar physics arise. For the sun must be supposed of equal duration, and we are required to assume impossible amounts of uranium to maintain his heat all that great lapse of time; and again this uranium would perish at just the same rate as that upon the earth, so that at the present time the solar mass must be, for by far the greater part, composed of inert materials of high atomic weight: the products of the transformations of the uranium family. The difficulty is best appreciated when we consider that even to maintain his present rate of heat-loss by radium supplies, some 60 per cent. of his mass must be composed of uranium. But there are other troubles to face if we adopt this view. The earth, or rather those parts of it which are sufficiently near the surface to lose heat at the requisite rate, would have cooled but one per cent. in 10^8 years. Shrinkage of the outer parts and crustal thickness will be proportionately small, and we must put back our epochs of mountain building to suit so slow a rate of cooling and shrinkage and refer the earlier events of the kind into a past of inconceivable remoteness. Otherwise we must abandon the only tenable theory of mountain formation with which we are acquainted. On such a time-scale the ocean would be supersaturated under the influence of the prolonged denudation like the waters of certain salt lakes, and the sediments would have accumulated a hundredfold in thickness.

Nor do the facts as we know them require from us such sacrifices. We are not asked to raise these difficulties on supposititious quantities of uranium for the existence of which there is no evidence. Radium has occasioned no questioning of the older view that the cooling of the earth from a *consistentior status* has been mainly controlled by radiation. But, on the contrary, this new revelation of science has come to smooth over what difficulties attended the reconciliation of physical and geological evidence on the Kelvin hypothesis. It shows us how the advent of the present thermal state might be delayed and geological time lengthened, so that Kelvin's forty or fifty million years might be reconciled with the hundred million years which some of us hold to be the reading of the records of denudation.

On this more pacific view of the mission of radium to geology, what has been the history of the earth? In the earlier days of the earth's cooling the radiation loss was far in excess of the radio-thermal heating. From this state by a continual convergence, the rate of radiation loss diminishing while the radio-thermal output remained comparatively constant, the existing distribution of temperature near the surface has been attained when the radio-thermal supply may nearly or quite balance the loss by radiation. The question of the possibility of final and perfect equilibrium between the two seems to involve the interior conductivity and in this way to evade analysis.

It will be asked if the facts of mountain building and earth-shrinkage are rendered less reconcilable by this interference of uranium in the earth's physical history. I believe the answer will be in the negative. True, the greatest development of crustal wrinkling must have occurred in earlier times. This must be so, in some degree, on any hypothesis. The total shrinkage is, however, not the less because delayed by radio-thermal actions, and it is not hard to point to factors which will attend the more recent upraising of mountain chains tending to make them excel in magnitude those arising from the stresses in an earlier and thinner crust.

Underground Temperature.

It would be a matter of the highest interest if we could definitely connect the rise of temperature which is observed in deep borings and tunnels with the radio-activity of the rocks. We are confronted, however, by the difficulty that our deepest borings and tunnels are still too near the surface to enable us to pronounce with certainty on the influence of the radium met with in the rocks. This will be understood when it is remembered that a merely local increase of radio-activity must have but little effect upon the temperature unless the increase was of a very high order indeed. A clear understanding of this point shows us at once how improbable it is that volcanic temperatures can be brought within a very few miles of the surface by local radio-activity of the rocks. To account on such principles for an elevation of temperature of, say, 1200° at a depth of three or four miles from the surface, a richness in radium must be assumed far transcending anything yet met with in considerable rock masses; and as volcanic materials appear to show nothing of such exceptional richness in radium we can hardly suppose local radio-activity of the upper crust responsible for volcanic phenomena.

When we come to apply calculation to results on the radio-activity of the materials penetrated by tunnels and borings, we at once find that we require to know the extension downwards of the rocks we are dealing with before we can be sure that radium will account for the thermal phenomena observed. At any level between the surface and the base of a layer of radio-active materials—suppose the level considered is that of a tunnel—the temperature depends, so far as it is due to local radium, on the total depth of the rock-mass having the observed radio-activity. This is evident. It will be found that for ordinary values of the radium content it is requisite to suppose the rocks extending downwards some few kilometres in order to account for a few degrees in temperature at the level under observation. There is, of course, every probability of such a downward extension. Thus in the case of the Simplon massif the downward continuance of the gneissic rocks to some few kilometres evokes no difficulties. The same may be said of the granite of the Finsteraarhorn massif and the gneisses of the St. Gothard massif, materials both of which are penetrated by the St. Gothard tunnel, and which appear to possess a considerable difference in radio-activity. In dealing with this subject, comparison of the results obtained at one locality with those obtained at another is the safest procedure. We must accordingly wait for an increased number of results before much can be inferred. I will now lay the cases of the two great tunnels as briefly as possible before you.

And first as to the temperature effects observed in the two cases.

The Simplon tunnel for a length of some seven or eight kilometres lies at a mean distance of about 1,700 metres from the surface. At the northerly end of this stretch the rock temperature attains 55°, and at the southern extremity has fallen to about 35°. The temperature of 55° is the highest encountered. The maximum predicted by Stapff, basing his estimates on his experience of the St. Gothard tunnel, was 47°. Other authorities in every case predicted considerably lower temperatures. Stockalper, who also had experience of the St. Gothard, predicted 36° at a depth of 2,050 metres from the surface, and Heim 38° to 39°.[1]

When the unexpectedly high temperatures were met with, various reasons were assigned. Mr. Fox has suggested volcanic heat. Others point to the arrangement of the schistosity and the dryness of the rocks, where the highest temperatures were read. The latter is evidently to be regarded more as explanation of the lower temperatures at the south end of the tunnel, where the water circulation was considerable, than of the high temperatures of the northern end. The schistosity may have some influence in bringing the isogeotherms nearer to the surface; however, not only are the rocks intensely compact in every direction, but what schistosity there is by no means inclines in the best directions for retention of heat. From the sections the schistosity appears generally to point upwards at a steep angle with the tunnel axis.[2]

Where there is such variability in the temperatures, irrespective of the depth of overlying rock, there is difficulty in assigning any significant mean gradient. The highest readings are obviously those least affected by the remarkable water-circulation of the Italian side. The higher temperatures afford such gradients as would be met in borings made on the level—about 31 metres per degree.

The temperatures read in the St. Gothard rocks were of a most remarkable character. For the central parts of the tunnel the gradients come out as 46·6 metres per degree. Stapff, who made these observations and conducted the geological investigations, took particular pains to ascertain the true surface temperatures of the rock above the tunnel; and from these ascertained temperatures, the temperatures in the tunnel rock and the overlying height of mountain, he calculated the gradients.

But this low gradient is by no means the mean gradient. At the north end, where the tunnel passes through the granite of the Finsteraarhorn massif, there is a rise in the temperature of the rock sufficient to steepen the gradient to 20·9 metres per degree. Stapff regarded this local rise of temperature as unaccountable save on the view that the granite retained part of the original heat. This matter I will presently return to.

Now, it is a fact that the radium-content of the Simplon rocks, after some allowance for what I have referred to as sporadic radium, stands higher than is afforded by the rocks in the central section of the St. Gothard, where the gradient is low. For the Simplon the general mean is (on my experiments) 7·1 billionths of a gram per gram. This mean is well distributed as follows:—

Jurassic and Triassic altered sediments	6·4
Crystalline schists, partly Jurassic and Triassic, partly Archæan	7·3
Monte Leone gneiss and primitive gneiss	6·3
Schistose gneiss (a fold from beneath)	6·5
Antigorio gneiss	6·8

The divisional arrangement is Professor Schardt's. Forty-nine typical rocks are used in obtaining these results, and the experiments have been in many cases

[1] See the account given by Schardt, *Verhandl. Schweizerischen Naturf. Gesellsch.* 1904, **87**, 'Jahresversammlung,' p. 204 *et seq.*

[2] Schardt, *loc. cit.*

repeated on duplicate specimens. Including some very exceptional results, the mean would rise to $9{\cdot}1 \times 10^{-12}$ grams per gram.

Of the St. Gothard rocks I have examined fifty-one specimens selected to be, as far as attainable, representative.[1]

Of these, twenty-one are from the central region, and their mean radium content is just 3·3. The portion of the tunnel from which these rocks come is closely coincident with Stapff's thermal subdivision of regions of low temperature.[2] This portion of the mountain offers the most definite conditions for comparison with the Simplon results. The region south of this is affected by water circulation; the regions to the north are affected by the high temperature of the granite.

We see, then, that the most definite data at our disposal in comparing the conditions as regards temperature and radio-thermal actions in the two tunnels appear to show that the steeper gradient is associated with the greater radium-content.

It is possible to arrive at an estimate of the downward extension of the two rock masses (assumed to maintain to the same depth their observed radio-activity), which would account for the difference in gradient. In making this estimate, we do not assume that the entire heat-flow indicated by the gradients is due to radium, but that the difference in radium-content is responsible for the difference of heat-flow. If some of the heat is conducted from an interior source (of whatever origin), we assume that this is alike in both cases. We also assume the conductivities alike.

Calculating on this basis, the depth required to establish on the radium measurements the observed difference in gradients of the Central St. Gothard and of the Simplon, we find the depth to be about 7 kilometres on the low mean of the Simplon rocks, and 5 kilometres on the high mean. There is, as I have already said, nothing improbable in such a downward extension of primitive rocks having the radio-activities observed; but as a different distribution of radium may, of course, obtain below our point of observation, the result can only claim to be suggestive.

Turning specially to the St. Gothard, we find that a temperature problem of much interest arises from the facts recorded. The north end of the tunnel for a distance of 2 kilometres traverses the granite of the Finsteraarhorn massif. It then enters the infolded syncline of the Usernmulde and traverses altered sediments of Trias-Jura age for a distance of about 2 kilometres. After this it enters the crushed and metamorphosed rocks of the St. Gothard massif, and remains in these rocks for 7½ kilometres. The last section is run through the Tessinmulde for 3 kilometres. These rocks are highly altered Mesozoic sediments.

I have already quoted Stapff's observations as to the variations of gradient in the northern, central, and southern parts of the tunnel. He writes: 'They (the isotherms) show irregularities on the south side, which clearly depend on cold springs, they bend down rapidly, and then run smoothly inclined beneath the water-filled section of the mountain. Other local irregularities can be explained by the decomposition of the rock; but there is no obvious explanation of the rapid increase in the granite rocks at the northern end of the tunnel (2,000 metres), and it is probably to be attributed to the influence of different thermal qualities of the rock on the coefficient of increase. For the rest these 2,000 metres of granite belong to the massif of the Finsteraarhorn, and, geologically speaking, they do not share in the composition of the St. Gothard. Perhaps these two massifs belong to different geological periods (as supposed for geological reasons long ago). What wonder, then, if one of them be cooler than the other.' (*Loc cit.*, p. 30.)

Commenting on the explanation here offered by Stapff, Prestwich[3] states

[1] I would like to express here my acknowledgments to the Trustees of the British Museum for granting me permission to use chips of the rocks in their possession; and especially to Mr. Prior for his valuable assistance in selecting the specimens.

[2] *Trans. North of England Mining and Mec. Engineers*, xxxiii. p. 25.

[3] *Proc. R.S.*, xli. p. 44.

his preference for the view that the excess of temperature in the granite is due to mechanical actions to which the granite was exposed during the upheaval of this region of the Alps.

The accompanying diagram shows the distribution of temperature as given by Stapff, and the distribution of radium as found from typical specimens of the rocks. There is a correspondence between the two which is obvious, and when it is remembered that the increase in radio-activity shown at the south end would have been, according to Stapff, masked by water circulation, the correspondence becomes the more striking. The small radium values in the central parts of the tunnel are remarkable. The rocks of the Central St. Gothard massif are apparently exceptionally poor in radium.

At the north end the excess of radium is almost confined to the granite, the rock to which Stapff ascribed the exceptional temperatures. The radium of the Usernmulde is probably not very important, seeing that these sediments cannot extend far downwards. The principal local source of heat appears located more especially beneath the synclinal fold, for Stapff's table (*loc. cit.*, p. 31) of the gradients beneath the plain of Andermatt shows a rising gradient to a point about 2,500 metres from the north entrance of the tunnel. It is observable that the radio-activity of the granite increases as it approaches the Usernmulde and attains its maximum (14·1) where it dips beneath the syncline.

The means of radium-content in the several geological sections into which the course of the tunnel is divisible are as follows:—

Granite of Finsteraarhorn	7·7
Usernmulde	4·9
St. Gothard massif	3·9
Tessinmulde	3·4

The central section, however, if considered without reference to geological demarcations, would, as already observed, come out as barely 3·3. And this is the value of the radio-activity most nearly applicable to Stapff's thermal subdivision of the region of low temperature.

If we accept the higher readings obtained in the granite as indicative of the radio-active state of this rock beneath the Usernmulde, a satisfactory explanation of the difference of heat-flow from the central and northern parts of the tunnel is obtained. Using the difference of gradient as basis of calculation, as before, we find that a downward extension of about six thousand metres would, if the outflow took place in an approximately vertical direction, account for the facts observed by Stapff. This depth is in agreement with the result as to the downward extension of the St. Gothard rocks as derived from the comparison with the Simplon rocks.

We are by no means in a position to found dogmatic conclusions on such results; they can only be regarded as encouragement to pursue the matter further. The coincidence must be remarkable which thus similarly localises radium and temperature in roughly proportional amounts, and permits us, without undue assumptions, to explain such remarkable differences of gradient. There is much work to be done in this direction, for well-known cases exist where exceptional gradients in deep borings have been encountered—exceptional both as regards excess and deficiency.

Radio-active Deposits and the Instability of the Crust.

At the meeting of the British Association held last year at Leicester, I read a note on the thermal effects which might be expected to arise at the base of a sedimentary accumulation of great thickness due to the contained radium.

The history of mountain building has repeated itself many times: ages of sedimentation, with attendant sinking of the crust in the area of deposition, then upheaval, folding up of the great beds of sediment, and even their overthrusting for many miles. So that the mountain ranges of the world are not constituted from materials rising from below, save in so far as these may form a sustaining core, but of the slowly accumulating deposits of the ages preceding the upheaval.

The thickness of collected sediments involved in these great events is enormous, and although uncertainty often attends the estimation of the aggregate depths of sedimentation, yet when we consider that unconformities between the deposits of succeeding eras represent the removal of vast masses of sediment to fresh areas of deposition, and often in such a way as to lead to an under-estimate of the thickness of deposit, the observations of the geologist may well indicate the minor and not the major limit. Witness the mighty layers of the Huronian, Animikean, and Keweenawan ages where deposits measured in miles of thickness are succeeded by unrecorded intervals of time, in which we know with certainty that the tireless forces of denudation laboured to undo their former work Each era represents a slow and measured pulse in the earth's crust, as if the overloading and sinking of the surface materials induced the very conditions required for their re-elevation. Such events, even in times when the crust was thinner and more readily disturbed than it is now, must have taken vast periods of time. The unconformity may represent as long a period as that of accumulation. In these Proterozoic areas of America, as elsewhere on the globe and throughout the whole of geological history, there has been a succession in time of foldings of the crust always so located as to uplift the areas of sedimentation, these upheavals being sundered by long intervals during which the site of sedimentation was transferred and preparation made for another era of disturbance. However long deferred there seems to be only the one and inevitable ending, inducing a rhythmic and monotonous repetition surely indicative of some cause of instability attending the events of deposition.

The facts have been impressively stated by Dana: 'A mountain range of the common type, like that to which the Appalachians belong, is made out of the sedimentary formations of a long preceding era; beds that were laid down conformably, and in succession, until they had reached the needed thickness; beds spreading over a region tens of thousands of square miles in area. The region over which sedimentary formations were in progress in order to make, finally, the Appalachian range, reached from New York to Alabama, and had a breadth of 100 to 200 miles, and the pile of horizontal beds along the middle was 40,000 feet in depth. The pile for the Wahsatch Mountains was 60,000 feet thick, according to King. The beds for the Appalachians were not laid down in a deep ocean, but in shallow waters, where a gradual subsidence was in progress; and they at last, when ready for the genesis, lay in a trough 40,000 feet deep, filling the trough to the brim. It thus appears that epochs of mountain making have occurred only after long intervals of quiet in the history of a continent.'

The generally observed fact that the deposition of sediments in some manner involves their ultimate upheaval has at various times led to explanations being offered. I think I am safe in saying that although the primary factor, the compressive stress in a crust which has ceased to fit the shrinking world within it, has probably been correctly inferred, no satisfactory explanation of the connection between sedimentation and upheaval has been advanced. The mere shifting upwards of the isogeotherms into the deposits, advanced as a source of local loss of rigidity by Babbage and Herschel, need not involve any such loss so long as the original distance of the isogeotherms from the surface is preserved.

We see in every case that only after great thicknesses of sediments have accumulated is the upheaval brought about. This is a feature which must enter as an essential condition into whatever explanation we propose to offer.

Following up the idea that the sought-for instability is referable to radiothermal actions, we will now endeavour to form some approximate estimate of the rise of temperature which will be brought about at the base of such great sedimentary accumulations as have gone towards mountain building, due to the radium distributed throughout the materials.

The temperature at the base of a feebly radio-active layer, such as an accumulation of sediments, is defined in part by radio-active energy, in part by its position relative to the normal isogeotherms, whether these latter are in turn due to or influenced by radio-thermal supplies or not. It is convenient, and I think allowable, to consider these two effects separately, and deal with them as if they were independent, the resultant state being obtained by their summation.

In dealing with the rise of temperature at the base of a radio-active layer we arrive at an expression which involves the square of the depth. This is a very important feature in the investigation, and leads to the result that, for a given amount of radium, diffuse distribution through a great depth of deposit gives rise to a higher basal temperature than a more concentrated distribution in a shallower layer.

But this will not give us the whole effect of such a deposit. Another and an important factor has to be taken into account. We have seen that the immediate surface rocks are of such richness in radium as to preclude the idea that a similar richness can extend many miles inward.

Now, it is upon this surface layer that the sediments are piled, and as they grow in thickness this original layer is depressed deeper and deeper, yielding under the load until at length it is buried to the full depth of the overlying deposit. This slow and measured process is attended by remarkable thermal effects. The law of the increase of temperature with the square of the depth comes in, and we have to consider the temperature effect not merely at the base of the deposited layer, but that due to the depression and covering over of the radium-rich materials upon which the sediments were laid down.

The table which follows embodies an approximate statement of the thermal results of various depths of deposit supposed to collect under conditions of crustal temperature such as prevail in this present epoch of geological history :—

Thickness of Sedimentary Deposit	Resulting Rise of Isogeotherms	Weakening of Earth's Crust as defined by the Rise of the Geotherm at 40 kilometres
Kilometres	Kilometres	Kilometres
6	7·4	40 to 32·6
8	10·2	40 to 29·8
10	13·3	40 to 26·7
12	16·7	40 to 23·3
14	20·4	40 to 19·6

I have deferred to the conclusion of this Address an account of the steps followed in obtaining the above results. It is clearly impossible, within the limited time allotted to me, to make these quite clear. It must suffice here merely to explain the significance of the figures.

The first column gives the depth of sedimentary deposit supposed to be laid down on the normal radio-active upper crust of a certain assumed thickness and radio-activity. From the rise of temperature which occurs at the base of this crust (due to the radio-activity, not only of the crust, but of the sediments) the results of the second column are deduced, the gradient or slope of temperature prevailing beneath being derived from the existing surface gradients corrected for the effects of the radio-thermal layer. The third column is intended to exhibit the effect of this shift of the geotherms in reducing the strength of the crust. I assume that at a temperature of 800° the deep-seated materials lose rigidity under long continued stress. The estimated depth of this geotherm is, on the assumptions, about 40 kilometres. The upward shift of this geotherm shows the loss of strength. Thus in the case of a sedimentary accumulation of 10 kilometres the geotherm defining the base of the rigid crust shifts upwards by 13 kilometres, so that there is a loss of effective section to the amount of 30 per cent.[1]

As regards the claims which such figures have upon our consideration, my assumptions as to thickness and radio-activity of the specially rich surface layer are, doubtless, capable of considerable amendment. It will be found,

[1] See Appendix B.

however, that the assumed factors may be supposed to vary considerably, and yet the final results prove such as, I believe, cannot be ignored. Indeed those who are in the way of making such calculations, and who enter into the question, will find that my assumptions are not specially favourable, but are, in fact, made on quite independent grounds. Again, a certain class of effects has been entirely left out of account, effects which will go towards enhancing, and in some cases greatly enhancing, the radio-thermal activity. I refer to the thickening of the crust arising from tangential pressure, and, at a later stage, the piling up and overthrusting of mountain building materials. In such cases the temperature of the deeper parts of the thickened mass must still further rise under the influence of the contained radium. These effects only take place, indeed, after yielding has commenced, but they add to the element of instability which the presence of the accumulated radio-active deposits occasions, and doubtless increase thermal metamorphic actions in the deeper sediments, and result in the refusion of rocks in the upper part of the crust.[1]

The effect of accumulated sediment is thus necessarily a reduction in the thickness of that part of the upper crust which is capable of resisting a compressive stress. Over the area of sedimentation, and more especially along the deepest line of synclinal depression, the crust of the globe for a period assumes the properties belonging to an earlier age, yielding up some of the rigidity which was the slow inheritance of secular cooling. Along this area of weakness—from its mode of formation generally much elongated in form—the stressed crust for many hundreds, perhaps thousands, of miles finds relief, and flexure takes place in the only possible direction; that is, on the whole upwards. In this way the prolonged anticline bearing upwards on its crest the whole mass of deposits is formed, and so are born the mountain ranges in all their diversity of form and structure.

We have in these effects an intervention of radium in the dynamics of the earth's crust, which must have influenced the entire history of our globe, and which, I believe, affords a key to the instability of the crust. For after the events of mountain building are accomplished, stability is not attained, but in presence of the forces of denudation the whole sequence of events has to commence over again. Every fresh accession of snow to the firn, every passing cloud contributing its small addition to the torrent, assists to spread out once more on the floor of the ocean the heat-producing substance. With this rhythmic succession of events appear bound up those positive or negative movements of the strand which cover and uncover the continents, and have swayed the entire course of evolution of terrestrial life.

Oceanic Deposits.—The displacements of the crust which we have been considering are now known to be by no means confined to the oceanic margins. The evidence seems conclusive that long continued movements have been in progress over certain areas of the sea floor, attended with the formation of those numerous volcanic cones upon which the coral island finds foundation. Here there are plainly revealed signs of instability and yielding of the crust (although, perhaps, of minor intensity) such as are associated with the greater movements which terminate in mountain building. I think it will be found, when the facts are considered, that we have here phenomena continuous with those already dealt with, and although the conditional element of a sufficient sedimentary accumulation must remain speculative, the evidence we possess is in favour of its existence.

One of the most interesting outstanding problems of deep-sea physiography is that of the rates of accumulation of the several sorts of deposit. In the case of the more rapidly collecting sediments there seems no serious reason why the matter should not be dealt with observationally. I hope it may be accomplished in our time.

[1] Professor C. Schmidt (Basel) has recently given reasons for the view that the Mesozoic schists of the Simplon at the period of their folding were probably from 15,000 to 20,000 metres beneath the surface (*Ec. Geol. Helvetiæ*, vol. ix. No. 4, p. 590). As another instance consider the compression of the Laramide range (Dawson, *Bull. Geol. Soc. Am.*, xii. p. 87).

For my present purpose I should like to know what may or may not be assumed in discussing the accumulation of radio-active sediments on the ocean floor.

As regards the rate of collection of the non-calcareous deposits, the nearest approach to an estimate is, I think, to be obtained from the exposed oceanic deposits of Barbados. In the well-known paper of Jukes Brown and Harrison [1] on the geology of that island, it is shown that the siliceous radiolarian earths and red clays aggregate to a thickness of about 300 feet. These materials are true oceanic deposits, devoid of terrigenous substances. They collected very probably during Pliocene and, perhaps, part of Pleistocene times. Now, there is evidence to lead us to date the beginning of the Pliocene as anything from one million to three million years ago. The mean of these estimates gives a rate of collection of 5 millimetres in a century. This sounds a very slow rate of growth, but it is too fast to be assumed for such deposits generally. More recent observations might, indeed, lead us to lengthen the period assigned to the deposition of these oceanic beds; for if, following Professor Spencer,[2] we ascribe their deposition to Eocene times, a less definite time-interval is indicated; but the rate could hardly have been less than three millimetres in a century. The site of the deposit was probably favourable to rapid growth.

We have already found a maximum limit to the average thickness of true oceanic sediments; and such as would obtain over the ocean floor if the rate of collection was everywhere the same and had so continued during the past. If there is one thing certain, however, it is that the rates of accumulation vary enormously. The 1,200 or 1,500 feet of chalk in the British Cretaceous, collected in one relatively brief period of submergence, would alone establish this. Huxley inferred that the chalk collected at the rate of one inch in a year. Sollas showed that the rate was more probably one inch in forty years. Sir John Murray has advanced evidence that in parts of the Atlantic the cables become covered with Globigerina ooze at the rate of about 10 inches in a century. Finally, then, we must take it that the fair allowance of one-seventh of a mile may be withheld in some areas and many times exceeded in others.

Now it is remarkable that all the conditions for rapid deposition seem to prevail over those volcanic areas of the Pacific from which ascend to the surface the coral islands—abundant pelagic life and comparatively shallow depths. Indeed, I may remind you that the very favourable nature of the conditions enter into the well-known theory of coral island formation put forward by Murray.

The islands arise from depths of between 1,000 and 2,000 fathoms. These areas are covered with Globigerina ooze having a radio-activity of about 7 or 8. The deeper-lying deposits around—red clay and radiolarian ooze—show radio-activities up to and over 50. From these no volcanic islands spring.

These facts, however, so far from being opposed to the view that the radio-activity and crustal disturbance are connected, are in its favour. For while those rich areas testify to the supply of radio-active materials, the slow rate of growth prevailing deprives those deposits of that characteristic *depth* which, if I may put it so, is of more consequence than a high radio-activity. For the rise in temperature at the base of a deposit, as already pointed out, is proportional to the square of the thickness; in reality the dilution of the supplies of uranium which reach the calcareous oozes flooring the disturbed areas is a necessary condition for any effective radio-thermal actions.

It might appear futile to consider the matter any closer where so little is known. But in order to give an idea of the quantities involved I may state that, if my calculations are correct, a rate of deposit comparable with that of the chalk prevailing for ten million years would, on assumptions similar to those already explained when discussing the subject of mountain building, occasion a rise of the deeper isogeotherms by from 20 to 30 per cent. of their probable normal depth.

In making these deductions as to the influence of radium in sedimentary deposits, I have so far left out of consideration the question of the time which mus

[1] *Q.J.G.S.*, xlviii. p. 210. [2] *Ibid.*, lviii. p. 354 *et seq.*

elapse in order that the final temperature-rise in the sediments must be attained. The question we have to answer is: Will the rate of rise of temperature due to radium keep pace with the rate of deposition, or must a certain period elapse after the sedimentation is completed to any particular depth, before the basal temperature proper to the depth is attained?

The answer appears to be, on an approximate method of solution, that for rates of deposition such as we believe to prevail in terrigenous deposits—even so great as one foot in a century, and up to depths of accumulation of 10 kilometres and even more—the heating waits on the sedimentation. Or, in other words, there is thermal equilibrium at every stage of growth of the deposit; and the basal temperature due to radio-active heating may at any instant be computed by the conductivity equation. For accumulations of still greater magnitude the final and maximum temperature appears to lag somewhat behind the rate of deposition.

From this we may infer that the great events of geological history have primarily waited upon the rates of denudation and sedimentation. The sites of the terrigenous deposits and the marginal oceanic precipitates have many times been convulsed during geological time because the rates of accumulation thereon have been rapid. The comparative tranquillity of the ocean floor far removed from the land may be referred to the absence of the inciting cause of disturbance. If, however, favourable conditions prevail for such a period that the local accumulations attain the sufficient depth, here, too, the stability must break down and the permanency be interrupted.

Upheaval of the ocean floor, owing to the laws of deep-sea sedimentation, should be attended with effects accelerative of deposition—a fact which may not be without influence. But although ultimately sharing the instability of the continental margins, the cycle of change is tuned to a slower periodicity. From the operation of these causes, possibly, have come and gone those continents which many believe to have once replaced the wastes of the oceans, and which with all their wealth of life and scenic beauty have disappeared so completely that they scarce have left a wreck behind. But those forgotten worlds may be again restored. The rolled-up crust of the earth is still rich in energy borrowed from earlier times, and the slow but mighty influences of denudation and deposition are for ever at work. And so, perchance, in some remote age the vanished Gondwána Land, the lost Atlantis, may once again arise, the seeds of resurrection even now being sown upon their graves from the endless harvests of pelagic life.

APPENDIX A.

Convective Movement of Uranium to the Earth's Surface (p. 680).—The estimate of temperature given assumes (1) that the mass of igneous material is spherical, and (2) that its surface is kept at constant temperature, heat escaping freely. The first assumption is in favour of increasing the estimate of temperature, and probably would not generally be true, especially of a mass moving upwards. The second assumption tends to give a lower estimate of temperature, and is certainly misleading, as the surrounding materials are non-conducting, and must favour the accumulation of radio-active heat.

On assumptions (1) and (2) and on Barus' results for the thermal expansion of diabase between 1100° and 1500°,[1] and results of my own on basalt,[2] which are in approximate agreement, and assuming the mean excess of temperature to be 500° and the surrounding material to be at a fluid temperature, the force of buoyancy comes out at over 60 dynes per cubic centimetre of the spherical mass. This is an under-estimate.

If we may assume that the Deccan Trap is indeed an instance of such an overheated mass escaping at the surface, and that similar radio-active masses rising up from beneath at various times in the past may have affected the crust, we have at our disposal a local source of energy of plutonic origin which may account for much.

[1] *Phil. Mag.*, xxxv. p. 173. [2] *Trans. R.D.S.*, vi. p. 298.

APPENDIX B.

Sedimentation and Rise of Geotherms (p. 692).—The depth of the upper radio-active layer is, of course, unknown. We possess, however, the means of arriving at some idea of what it must be. The quantitative thermal conditions impose a major limit to its average thickness, and the indications of injected rocks suggest a minor limit.

It will be found that if $2{\cdot}6 \times 10^{20}$ calories is the heat output of the whole earth per annum, and if we assign only one-fifth of this amount to cooling due to decay of the uranium, then, on the assumption that the earth is no longer losing any part of its original store of heat, we have about 2×10^{20} representing radium heating. From this the allowance of terrestrial radium per square centimetre inwards is $2{\cdot}3 \times 10^{-5}$ grams. This would give a major limit. But it is almost certain that some of this radium is located in more deeply seated parts of the earth. If we take 10^{-5} as contained in the normal radio-active surface layer, and assume (what according to my experiments should not be far from the truth) that the average radio-activity is 3, we arrive at a thickness of 12 kilometres.

Some such mean value is necessitated by the evidence we derive from the radio-activity of igneous rocks. These rocks must in many cases be derived from considerable depths. Such outflows as the Deccan may indicate local sub-crustal conditions; so also may the eruptions of certain volcanic areas. But those extrusions which have attended mountain building, more especially its closing phases, appear to indicate general conditions, and involve the existence of such radio-active materials at considerable depths. If we assume a thickness for the radio-active part of the crust much less than the 12 kilometres, difficulties are met with on this line of reasoning.[1]

Proceeding now to the derivation of the results given in the table, p. 692. The equation $k\theta = qhx(D - \frac{x}{2})$ (where θ is the temperature at the depth x, D being the total depth of the radio-active layer, q the radium per c.c. in grams, h the heat output of one gram of radium per second, k the thermal conductivity) is easily derived by considering the conditions of thermal flow in the layer, supposed to lose heat only at the surface.[2]

The aggregate depths of radio-active material in the several cases of sedimentary deposit assumed in my Address amount to 18, 20, 22, 24, and 26 kilometres. I assume the mean radio-activity to be 3·5, and the average conductivity to be 4×10^{-3}. From this the basal temperatures are found, as due to radio-thermal actions. These temperatures are to be augmented by the temperatures proper to the several depths, which depend upon the conducted interior heat. To estimate these we require to apportion the observed average surface gradient (taken as 32 metres per degree) between radio-active effects in the upper layer and the flow of heat from within. The radio-thermal gradient comes out at about 75 metres; the inner gradient is accordingly 56 metres. Hence the total temperature at the base of each radio-active mass is obtained. But the geotherms proper to the several depths, 18, 20, &c., kilometres, under conditions prevailing elsewhere in the crust, are easily found from the value of θ for the normal layer (82° C.), and adding the temperature due to interior heat. From the difference of the temperatures we, finally, find the rise of the geotherms.

As conveyed in my Address, I have found on several different values of the thickness and radio-active properties of the surface layer, results in every case showing large values for the rise of the geotherms. The data assumed above are by no means the most favourable.

[1] See p. 693, *ante*, and foot-note as bearing on the possible displacement of the geotherms.

[2] See Strutt, *Proc. R.S.*, lxxvii. p. 482.

The following Papers were then read:—

1. *The Geology of the Dublin District.* *By* Professor GRENVILLE A. J. COLE, *F.G.S.*

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2. *On the Cave of Castlepook, near Doneraile, Co. Cork.* *By* R. J. USSHER, H. J. SEYMOUR, E. T. NEWTON, *and* R. F. SCHARFF.

Castlepook Cave, north of Doneraile, leads into an extensive series of deep parallel galleries in limestone. Most of them are narrow, with vertical sides up to a certain level, where the walls recede with a wide sweep, forming an arched tunnel. Near the top of this the galleries are still spanned in places by an ancient stalagmite floor. Some of the sand on which the latter was formed is still adhering to it underneath. Beds of sand filled the lower parts of many galleries. This sand contained, sometimes down to 12 feet, numerous remains, chiefly of reindeer.

The geological evidence as to the age of the cave is unsatisfactory. Only rolled and unstriated pebbles have yet been discovered in the cave and no foreign erratic. This would seem to indicate that the material now in the cave, and hence the cave itself, is pre-glacial in age, for otherwise a pebble of the granite known to be widely distributed throughout the overlying boulder-clay might reasonably have been expected to occur amongst the large number of boulders found in the various passages. No such pebble has, however, been found. The inference, therefore, on more or less negative evidence, is that the cave was formed in pre-glacial times.

The bird remains found in the cave call for no special remarks. More than half are referable to the domestic fowl, turkey, and duck, though some of the latter may belong to the wild form. Like the bones of the rook, which are also numerous, they may have been brought in recently by foxes. The remainder all belong to such species as are now found in the neigbourhood.

The mammalian remains are of a very different character. It is true that the bones of the rabbit, sheep, ox, horse, pig, fox, cat, and rat seem mostly of comparatively recent origin. By far the greatest number of the bones found belong to the reindeer and bear. The exceedingly numerous bone splinters, the gnawed bones of reindeer, and the presence of many bones of old and young hyænas seem to indicate coexistence in Ireland of the latter and the typically arctic species. The hyæna, which had not previously been known to have ever inhabited Ireland, is closely related to that now living in South Africa. Other animals whose remains were probably dragged into the cave by hyænas, are the mammoth, Irish elk, red deer, and wolf. Among the smaller mammals the bones and teeth of the Arctic Lemming (*Dicrostonyx torquatus*) and of the Scandinavian Lemming (*Lemmus lemmus*) are very abundant. They may have been brought in by the Arctic fox.

No human remains or implements were found except parts of modern iron tools and charred wood indicating the presence of man only within quite recent times.

In so far as Ireland is not generally believed to have been joined to England by land in glacial or post-glacial times, the presence in the country of the mammoth, Irish elk, and hyæna apparently confirms the opinion, arrived at from geological evidence, that Castlepook Cave must be a pre-glacial one. This view is supported by the absence of many animals from Ireland which seem to have made their first appearance in England during the glacial period.

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3. *Probable Cretaceous and Cainozoic Outliers off the Coast of Co. Kerry.* *By* Professor GRENVILLE A. J. COLE, *F.G.S.*

The dredgings made since 1901 by the Fisheries Branch of the Department of Agriculture and Technical Instruction for Ireland have amply supported the conclusions then put forward,[1] to the effect that the geological structure of the

[1] Cole and Crook, *Report on Fisheries of Ireland for* 1901.

sea-floor off western Ireland can be deduced from a study of the stones lying on it from point to point. The most interesting recent results are the discovery of abundant flints, chalk, glauconitic chalk, and two specimens of Miliolina limestone in dredgings off the coast of Kerry. Mr. Worth's observations in 1908 on similar materials in the English Channel thus receive confirmation from areas much further west, and it is clear that both the Cretaceous and Eocene seas extended to an unknown distance in that direction, though we can trace their boundaries fairly on the north-west. Many of the flints of southern Ireland may have been derived from local strata rather than from ice-borne drift.

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4. *On a Section of the Lower Coal Measures at Emerald Pit, Dungannon.* By H. Bolton, *F.R.S.E., F.G.S.*

A shaft was sunk in 1894–5 some little distance to the north of the old Drumglass colliery, and was carried to a depth of 197 yards, penetrating five coal-seams before reaching the Main Coal, which was known to the miners as the 'Congo' seam. During the course of the sinking a measured section was obtained of the strata passed through, and a collection of fossils brought together. After work had commenced on the deeper coal-seams, water broke into the colliery on two occasions, causing its abandonment. A generalised section of the measures passed through is as follows:—

			ft.	in.	yds.	ft.	in.
	Strata				46	2	7
1.	Coal (inferior)					1	10
	Strata				3	2	2½
2.	Coal						½
	Strata				65	2	3
3.	Coal (in thin partings with shale)				2	0	5
	Strata				44	0	11
4.	Coal						3
	Strata				25	0	5
5.	Coal	Top Coal	1	0	1	0	10
		Brown Shale		7			
		Coal	1	3			
		Inferior Coal		3			
		Coal		9			
	Strata				5	0	6
6.	Coal					3	3

Down to the level of the 4th Coal, the strata consisted mainly of red, yellow, and grey sandstones, with grey bind partings. Below the 4th Coal, black and grey shales predominated. At a depth of 133 yards from the surface occurred a black shale containing a typical Lower Coal measures marine fauna.

The following species have been determined:—

Brachiopoda—
- *Discina nitida.*
- *Lingula squamiformis.*
- *Spirifera trigonalis.*
- *Camarophoria isorhynoha?*
- *Chonetes*, sp.

Pelecypoda—
- *Sanguinolites plicatus*, Portlock.
- *Nucula gibbosa.*
- *Nuculana attenuata.*
- *Protoschizodus axiniformis.*
- *Parallelodon*, cf. *Verneuillianus*, de Kon.

Gasteropoda—
- *Pleurotomaria*, cf. *gemmulifera.*

Cephalopoda—
- *Orthoceras Koninckianum* ? d'Orb.

Vermes—
- *Serpulites membranaceous.*

Fishes—
- Palæoniscid scale and tooth.

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5. *On the Raised Beeches of the Liffey Valley.* *By* G. H. Kinahan.

FRIDAY, SEPTEMBER 4.

The following Papers and Report were read:—

1. *On the Igneous Rocks of the Outer Blasket Islands.* *By* Professor J. Joly, *F.R.S.*

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2. *The Laterite and Bauxite Zone of North-East Ireland.* *By* Professor Grenville A. J. Cole, *F.G.S.*

This paper was merely explanatory of an exhibit of the types of rock formed during the interval between the basaltic eruptions in the north of Ireland in Eocene times. It was urged, in agreement with the views of Richardson and Tate and Holden, that the red lateritic zone represents basalt altered *in situ* even down to depths of 40 feet, the so-called 'volcanic bombs' in the layer being residual lumps of less altered basalt. Such a type of alteration is clearly connected with the climatic conditions of Eocene times. Some of the pisolitic iron-ore may have accumulated on the surface of the laterite in pools formed during the rainy seasons. The pale bauxites are derived from sporadic eruptions of rhyolite, and the bi-pyramidal crystals of quartz in them prove this over a wide area. The thin bauxitic layer, occurring as it does above the pisolitic iron-ore, may be in part formed by wind-borne material.

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3. *The Igneous and Associated Sedimentary Rocks of the Tourmakeady District, Co. Mayo.* *By* C. I. Gardiner *and* Professor S. H. Reynolds.

The oldest rocks are a series of grits, conglomerates, black slates, cherts, and tuffs exposed along the eastern side of the area. The slates have yielded a large series of graptolites, which indicate that the rocks are of Upper Arenig age. Further to the west occur gritty tuffs and limestones, often of a peculiar brecciated character, which have yielded a considerable series of fossils of Llandeilo type. Quartz felsites, probably both intrusive and contemporaneous (rhyolites), play a very prominent part throughout the district.

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4. *The Lower Palæozoic Rocks around Killary Harbour, Co. Galway, and Co. Mayo.* *By* R. G. Carruthers *and* H. B. Muff.

The following succession was found in the Ordovician and Silurian rocks around Killary Harbour:—

1. *Tetragraptus* zone (Middle Arenig).—Black shales and cherts, 60 feet thick, with *Tetragraptus* (four species), *Dichograptus octobrachiatus, Didymograptus extensus,* and other forms, including two species of *Diplograptus* new to the British Isles but known in North America.
2. *Diplograptus dentatus* zone (Upper Arenig).
   (*a*) Leenane Grits, following conformably above the cherts on the south shore of Killary Harbour. Conglomeratic grits with slate bands coming in towards the west in Rossroe, and a lenticular bed of

brecciated limestone about 1,000 feet from the base. About 2,500 feet thick (top not seen). *Diplograptus dentatus, Phyllograptus, Didymograptus extensus,* and *D. fasciculatus.*

(*b*) Doolough Slates, on north side of Killary Harbour. Green slates, with subordinate grit bands, with *Diplograptus dentatus, Phyllograptus* (four species) and other forms, including a N. American species of *Glossograptus* and a new form, *G. acanthus.* E. & W. MS.

3. *Mweelrea Grits* (Llandeilo and (?) Bala).—Current-bedded red and greyish-green, felspathic grits, resting conformably on the Doolough Slates. Apparently 12,000 feet thick (top not seen). Green shale bands in lowest 3,000 feet, with *Ogygia* and brachiopods. Uppermost 9,000 feet barren.

4. *Owenduff Beds* (Upper Llandovery and Wenlock).—Basal breccia, with fragments of schist, rests unconformably on the Connemara Crystalline Schists and is succeeded by red mud-stones, barren green grits, calcareous grits with brachiopods, a coarse conglomerate containing quartzite boulders, and a thick series of greywacke grits and green sandy shales, in all about 5,300 feet thick. About 2,300 feet from the top is a band containing *Monograptus Riccartonensis,* and about 300 feet from the top another containing *Monograptus vomerinus* and other fossils.

5. *Salrock Slates* (Ludlow).—A monotonous series of dull Indian red and pale green slates overlying Owenduff Beds conformably. A few bands contain *Lingula Davisi, L. Symondsi,* &c. About 3,000 feet thick (top not seen).

The strata are arranged in a general east and west syncline through which, along the south side of Killary Harbour, runs the great reversed fault of Salrock Pass, hading to the north, and bringing up Arenig rocks on to Ludlow and Wenlock beds.

All the rocks are more or less cleaved, but the folding is on the whole quite gentle, although in the northern part of the district the Doolough Slates show considerable compression and packing from the north against the great mass of the Mweelrea Grits, and at the same time an appreciable development of sericitic mica.

The Arenig conglomerates contain boulders of quartzose schist identical with some of the Connemara Crystalline Schists. Hence the latter were metamorphosed before Arenig times, and are presumably of Archæan age.

5. *Notes on the Petrography of Egypt.* *By* W. F. Hume, *D.Sc.*

1. The ancient core of the North-east African continent consists of the Cataract and Sudan Banded Gneisses, which may represent a very ancient igneous magma. They are usually much veined by granitic dykes.

2. In certain places in the Arabian Desert, Cataracts, &c., these underlie highly metamorphosed Schists (the Mica-Schists of Sikait, the Calcareous Schists of Um Garaiart and Haimar and of the Amara Cataracts, also the Dolomites of the latter region), which are sharply separated from the *Banded Gneisses,* and are possibly the oldest sedimentary representatives in Egypt.

3. The greater part of the mountainous regions of the Eastern Desert and Sinai are occupied by two types of rock, a schistose constituent overlying or being surrounded by the acid member (*a*) the first-named, the *Dokhan Volcanic Rocks* and *Schists,* are partly volcanic in origin and partly sedimentary, the former being represented by lavas of various types, while the latter are clearly altered sedimentary strata (grits, conglomerates, &c.). No fossils have yet been found, but they have their nearest analogues in the latest pre-Cambrian and Cambrian series. Here are included some of the most interesting rocks of Egypt, such as the Imperial Porphyry and the Breccia Verde Antico.

(*b*) The igneous member intruded into these ancient sediments, &c., includes a great diversity of igneous rocks, varying from highly basic to acid types. Contact phenomena of complex nature occur at the junctions of *a* and *b*.

4. *Red Granite* and Dyke Rocks, whose parallelism and extent of distribution present one of the most conspicuous features of the Eastern Desert of Egypt, mark the final eruptive action before Carboniferous times.

5. Three periods of volcanic activity have been subsequently noted.

(*a*) In Western Sinai in late Carboniferous times.
(*b*) An undated series of eruptions interbedded with the base of the Nubian Sandstone or intrusive into it with marked contact alterations.
(*c*) The Basic Intrusions near Cairo and the Fayum, &c., which are intimately associated with the Oligocene Continental Period in Egypt.

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6. *The Chemical Composition and Optical Characters of Dolomite Crystals from Algeria.* *By* A. Hutchinson, *M.A., Ph.D.*

Fine crystals of dolomite are found at Biskra. As the material is perfectly colourless and transparent, it was thought that a careful chemical and optical examination would be of interest.

The results of an analysis were as follows :—

FeO	0·75	or	$FeCO_3$	1·22
CaO	30·31	„	$CaCO_3$	54·09
MgO	21·62	„	$MgCO_3$	45·20
CO_2	47·45			100·51
	100·31			

The indices of refraction were determined by means of a prism cut from the crystal which afforded material for analysis. The values obtained for the monochromatic flames given by lithium, sodium, and thallium respectively were—

	Li	Na	Tl
Ord.	1·5002	1·5022	1·5042
Extraord.	1·6767	1·6813	1·6855

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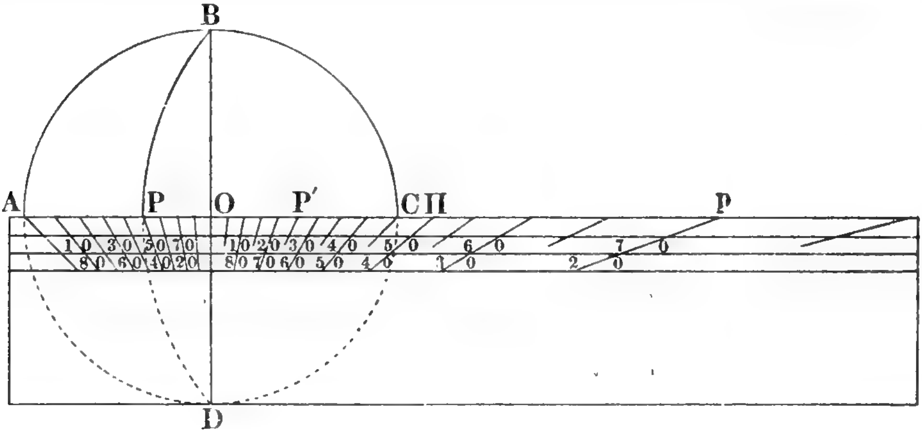
7. *A Protractor for constructing Stereographic and Gnomonic Projections of the Sphere.* *By* A. Hutchinson, *M.A., Ph.D.*

The protractor, which has been designed for the use of students of crystallography, consists of a rectangular strip of boxwood of any convenient length and thickness, and of a width exactly equal to the radius of the sphere to be projected. Experience has shown that 2·5 inches is a suitable radius for this sphere; the protractor must therefore be 2·5 inches wide, and should be about 12 inches long. A zero line OD is drawn across it at right angles to its length, at a distance from one end rather greater than the width of the protractor. Taking as centre the point D, the opposite edge is graduated by means of a circular dividing engine. The portion of the scale to the right of O is divided to degrees, and the divisions numbered as shown in the figure, in which, however, for the sake of clearness, the finer divisions have been omitted. The divisions from O to A are exactly the same as those from O to C, but are numbered differently, each division between O and C representing 2° instead of 1°.

From the method of construction it appears at once that the distance from O of any division lying to its right is numerically equal to the tangent of the corresponding angle (read on the upper row of numbers) when measured with a scale for which the radius of the primitive circle DABC is taken as unit. Such a scale is provided on the back of the protractor. Similarly, the distance from O of any division on the scale OA is numerically equal to the tangent of half the angle as read on the lower row of numbers, and the divisions themselves correspond to degrees stereographically projected on a diameter.

Since the graduation of Op is identical with that of the ordinary rectangular protractor, this scale may be used in the usual way for setting-off angles. So far as special applications are concerned, the two scales Op and OA, used separately or in conjunction, enable us to solve with ease the following problems of construction:—

(1) To project on any diameter the position of a point P, of which the angular distance from the primitive or from the North pole is known. In the figure P is the projection of a point 50° from the primitive.



(2) To draw through any point P a great circle BPD perpendicular to that projected in AOC. The centre of this circle lies at π, a point which has the same reading on the right-hand scale that P has on the left.

(3) To find the pole P′ of any projected great circle BPD, or in general to find the point 90° removed from a given point and lying in the same diameter.

(4) To find the projected position p of a face parallel to a face of which the projected position P is known. In other words, to find the point diametrically opposite to any given point.

(5) To draw small circles about any given point.

The protractor may also be employed with advantage in constructing gnomonic projections, as points of which the North polar distances are known can be plotted at once from the scale Op. It will also be found useful in measuring the angles between faces and zones on the completed projection.

8. *Notes on the Microscopical Structure of the Derbyshire Limestones.* *By* H. H. Arnold-Bemrose, *Sc.D., F.G.S.*

These notes form only a brief sketch of the results of a cursory examination of some four hundred thin slices of Derbyshire limestone in the author's collection. The specimens have been examined from a petrographical rather than from a palæontological point of view. The classification of microscopical types given in this short paper must be considered as provisional because of the few specimens examined from a large area of country, and from a thickness of over 1,800 feet of limestone shales and mountain limestone, in addition to the Permian limestones.

I. *Limestone Shales and Mountain Limestone.*

These may be divided into fine and coarse grained rocks.

Fine-grained limestone, as seen in the black limestone shales in the black upper beds of mountain limestone, associated with chert, and in some beds of white mountain limestone. These rocks have little definite structure under the microscope. In some cases, especially in the limestone shales, they contain sponge spicules.

Some of the massive white limestones have a micro-granular or micro-oolitic structure, like the limestones above the upper lava flow of Millers Dale. The granules consist of pellets and small oolitic grains with minute fragments of organisms.

Many limestones, both black and white, are composed mainly of foraminifera, with or without minute shell fragments, often enclosed in a calcite cement. (Foraminifera are present in most of the specimens examined.)

The coarse-grained limestones consist of granular and shelly limestones. The granular type includes the oolitic and the pebbly. One or both of these may be present in the same thin slice. The oolitic grains often have a nucleus of a fossil fragment. The pebbles consist of previously consolidated limestone, with fossil contents, and are evidently detrital. The granular structure is found at various horizons, and in many parts of the mountain limestone district. It frequently occurs above a bed of clay or of volcanic tuff, and has probably been formed in shallow water. The interspaces between the pebbles, oolitic grains and fossil fragments form about 25 per cent. of the whole rock. They are composed of crystalline calcite, and, according to Dr. Sorby's experiments, the rock has been subjected to considerable pressure previously to the infiltration of calcite. The shelly limestones contain fragments of brachiopods and productus which are waterworn. In some rocks there is a more or less laminated structure, resulting in a compact limestone, with few if any interspaces; in others the shell fragments have interspaces between them. Often associated with the granular limestones are fossils which have not been previously described, and which may be new forms of calcareous algæ.

Metamorphic Limestones.

Metamorphism by contact with intrusive igneous rocks is found both below and above the latter. The limestones have become marmorised or converted into crystalline calcite.

Metasomatic Limestones

consist of a replacement of the original limestone by crystalline silica or quartz, or by the double carbonate of lime and magnesia.

The former results in a rock consisting entirely of quartz. The changes from a limestone free from quartz, through limestones with quartz crystals and a quartzose limestone to a quartz rock, may be easily traced.

The latter change takes place when the carbonate of lime has been replaced by dolomite. In this case specimens can be obtained showing the various stages of replacement.

II. *The Permian Limestones*

in the eastern part of the county consist of more or less well-defined rhombohedra of dolomite with few angular grains of quartz. The white and red sandstones of the same district, which apparently lie below the limestones, contain more numerous angular grains of quartz in a dolomitic base, and compose about one-fourth of the rock. The latter rocks may therefore be termed dolomitic sandstones or quartzose dolomites.

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9. *On the Occurrence of Native Iron in the Deccan Basalt.* *By* Professor J. Joly, *F.R.S.*

10. *The Tourmaline Rocks of Cwm Dwythwc, near Llanberis (North Wales).* *By* W. G. FEARNSIDES, *M.A.*

Some years ago, when examining sands from the neighbourhood of Caernarfon, I found that both the river sands of the Seiont and the beach sands of the Menai contain tourmaline. In order to trace the mineral to its source I have since examined the heavy mineral residues of the sands of nearly all the tributaries of the Seiont, and find that all those which flow across the Cambrian Slate Belt contain either needles or broken grains of brown tourmaline. The sand from the Afon Arddu (whose delta parts the two lakes of Llanberis) is exceptional, and is very rich in well-formed trigonal prisms of blue tourmaline. The sand from the Afon Hwch, its tributary from between Moel Eilio and Moel Goch, is even more surprising, and in the sand from the spits along the flatter reaches of this burn tourmaline can generally be distinguished with a pocket lens.

I have therefore mapped the Cwm Dwythwc on the 6-inch scale, and in mapping have found the tourmaline rocks *in situ.* They are mostly coarse grits, grits, flags, and slaty flags, and occur along the horizon of the unconformity between Cambrian and Ordovician rocks. The tourmaline is not clastic but has been formed *in situ* from the feldspathic ground-paste of the grits or flags, and clustered new-formed needles enter and pierce the quartz pebbles of the grit or the chloritoid ground mass of the slate in a most fascinating manner. There has been much thrust-faulting along the unconformity, but no large intrusive mass of igneous rock has been observed within five miles of the locality. Tourmaline new-formed in the slate and the remains of tuning-fork graptolites can be found within three or four inches of each other. The tourmaline is a soda-bearing variety.

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11. *Note on the Occurrence of (so-called) Cave Pearls.* *By* HAROLD BRODRICK, *M.A.*

Cave pearls, as they were first called in 'Cave Hunting' (Professor Boyd Dawkins), seem to be of comparatively rare occurrence. They consist of a nucleus of some foreign material, frequently a small pebble of Yoredale rock (in one case a small fragment of lead ore) coated by numerous concentric rings of calcite. All those that I have found have been formed under similar conditions; they have all been found in what might be called nests in the rock, into which drops of water have fallen at comparatively long intervals from a considerable height. Each falling drop will have the tendency slightly to turn the nucleus, and also, by deposition, to coat it with a thin film of carbonate of calcium; this deposition is continued until what is called a cave pearl is formed, ranging in diameter from 0·5 cm. up to 2 cm.

The three types with which I am acquainted come from three separate caves: (1) The Blue John (Derbyshire). This type consists of a nucleus of Yoredale Sandstone covered with layers of calcite, which become harder towards the outside, the exterior being extremely hard, smooth, and opaque; sp. gr. 2·75. (2) The Bagshawe (Derbyshire). This type consists in many cases of a nucleus of Yoredale Sandstone, or, in one case at least, of lead ore; the concentric deposit in this type is somewhat translucent, the outer surface is slightly crystalline; sp. gr. 2·71. (3) Marble Arch (Co. Fermanagh). This type has a nucleus of Yoredale Sandstone, while the covering is composed of carbonate which seems to have included in it a considerable admixture of contained mud; the colour is a dirty grey, and the deposit is comparatively soft; sp. gr. 2·40. As will be seen from the specific gravity in each case, the deposit is in the form of calcite, a condition which might be anticipated from the mode of occurrence. I have carefully examined active streams in numerous caves for similar formations, but have been unable to find them. The caves in which they have been found (to my knowledge) are Caldy Island (Boyd Dawkins), the Blue John Cave (two nests), the Bagshawe Cave (one nest), about thirty pearls; Marble Arch Cave (one nest), at least a hundred pearls.

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12. *The Derivation of Sand and Clay from Granite.* *By* Professor W. Boyd Dawkins, *D.Sc., F.R.S.*

The decomposition of granite by the attack of the carbonic acid in the rain-water on the soluble crystalline elements of granite results in the formation of a surface-covering more or less complete over the solid rock which can only be studied in non-glaciated regions. It is conspicuous by its absence from the ice-swept granite areas of the Lake country, of Scotland, and of Ireland, and of Middle and Northern Europe.

The quartz in the granite has resisted decomposition, and where the finer products of decomposition have been swept away form a coarse sand, each grain presenting an irregular surface indented by the feldspars and micas as they cooled from the heated magma. These are traceable more or less through a large number of sandstones, and more especially through those of the Millstone Grits and Coal-measures of Middle and Northern England.

The attack of the rain-water containing carbonic acid on the micas results in the decomposition of the biotite and to a lesser degree of the muscovite, while the soluble feldspars, such as orthoclase, are completely dissolved, constituting hydrated silicates of alumina and new minerals such as kaolinite and secondary minutely crystalline muscovite. All these occur in the china clay of Cornwall and Devon, and are invariably associated with grains of quartz, primary mica, and tourmaline present in the unaltered granite. All these elements occur in all the samples ranging from the purest china clay through the whole series which have as yet been examined, with the addition of others of local derivation.

These facts indicate that granite has been one of the chief sources, not merely of the arenaceous, but also of the argillaceous rocks. It is not improbable that both may ultimately be proved to have been derived from the siliceous acid layer believed by Durocher and Haughton to have been the first to become solid in the cooling globe.

13. *Interim Report on the Microscopical and Chemical Composition of Charnwood Rocks.*

MONDAY, SEPTEMBER 7.

The following Papers and Reports were read:—

1. *Glacial Erosion in North Wales.* *By* Professor W. M. Davis.

The mountains of the Snowdon district are believed to represent a group of monadnocks which surmounted the peneplain to which a large part of the region was reduced in Tertiary time. The valleys between the monadnocks were somewhat deepened by normal erosive processes, in consequence of a general elevation of the region in late Tertiary time. As a result, the topography of the Snowdon district in immediately pre-glacial time may be described as exhibiting a group of well-subdued mountains, drained through valleys of somewhat sharpened form. The difference between the forms thus described and the forms seen to-day in the Snowdon district is very great, both in amount and in kind, and cannot be accounted for by normal erosion during glacial and post-glacial time. But the difference is, in amount and kind, just what might result from glacial action, if it be postulated that glaciers are effective eroding agencies. The depth of glacial erosion in certain cwms and valleys is believed to have been 400, 600, or 800 feet; the breadth of glacial erosion must have been of even greater measure.

2. *The Duration and Direction of Large Earthquakes.* *By* Dr. John Milne, *F.R.S.*

Small earthquakes, as for example those which occur in this country, have a duration of a few seconds near to their origin. At places 50 or 100 miles distant they may not be recordable. The duration, therefore, has varied between a few seconds and zero. With many large earthquakes, however, this decay during transmission is not appreciable, and duration near to their antipodes may be as great as it is near to their origin. Duration as one of these disturbances travels, rather than decreasing, at times appears to increase. The greatest duration is at about 90° distance from an origin. That which occurs may be compared with what we observe after a flask of water has been tilted. The contents oscillate like a pendulum, and any one part of the fluid comes to rest about the same time as any other part.

Another observation in connection with recent seismological observations is that large earthquakes travel furthest in particular directions. I have taken seventy-nine large disturbances with fairly well-known origins south of the Caucasus, north of India, and to the east or south of Japan. These earthquakes have travelled further to the west than to the east, and there has only been a small percentage of them that have found their way across the equator, to observatories in the southern hemisphere.

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3. *Report on the Excavation of Critical Sections in the Palæozoic Rocks of Wales and the West of England.*—See Reports, p. 231.

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4. *The Soufrière of St. Vincent: the Changes subsequent to the Eruption of* 1902. *By* Dr. Tempest Anderson, *F.G.S.*

In 1902 the author visited St. Vincent, along with Dr. Flett, after the then recent eruption. In 1907 he revisited the island and examined the changes that had taken place in the new deposits.

In 1902 an incandescent avalanche descended into the valleys which occupy the great tranverse depression across the island to the south of the Soufrière, and in particular the Wallibu Valley was filled for a great part of its course to a depth of at least 100 feet, but less near its mouth. In this deposit of red-hot material the secondary phenomena of re-excavation of the valley by the river, the falls of hot ash, the steam explosions, and the flows of boiling mud took place, and are described in the Report, Part I.[1] In 1907 almost the whole of this ash had been washed away, but a fragment remained in the shape of a terrace, 60 to 80 feet high, situated on the north side of the valley. The ash of which it is formed is unstratified, and contains very few ejected blocks or fragments of any kind. The floor of the valley is all composed of water-sorted material, chiefly gravel and coarse sand, but with a good many blocks as big as a man's head. They represent ejected blocks and fragments of lava derived partly from the ash of 1902 and partly from older beds, the fine ash in each case having been washed away. The surface of the gravel bed showed marks of quite recent running water, and during the last winter (1906-7) the river ran along the foot of the north bank of the valley. When examined in March 1907, it ran along the south side of the valley, and had already in those few months excavated a new channel about 30 feet in depth. The stratification, as exposed in this new valley, is very distinct, and the sorting by water, mentioned above, is very evident. Further up the mountain the remains of the avalanche became more abundant in the valley bottoms, and here they were also better preserved, so that traces of the feather-pattern erosion, so noticeable in 1902, were still visible on the surface. This was mainly due to the surface of these ash deposits, like those to be presently

[1] Anderson and Flett, *Phil. Trans.*, Series A, vol. 200, 1903; Anderson, *Geographical Journal*, March 1903.

mentioned on the plateaux and on the ridges, having consolidated into a crust, almost like a cement pavement, which resists the action of the rain.

Another interesting point was observed with regard to these massive beds of recent material. Instead of one stream re-establishing itself along the centre of the deposit, the tendency is for a new stream to form on each side at or near the junction of the new ash with the old valley slopes; and as these streams deepen their beds two new valleys are formed where only one previously existed, and the walls of each are composed on the one side of the new ash and on the other of older tuff, with occasional terraces.[1]

An account was also given of a visit to Montagne Pelée, in Martinique, with a discussion of the phenomena of the extrusion of and subsequent destruction of the spine which have been described by Lacroix and others, and a comparison of the eruptions of the two islands.

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5. *Recent Earth Movements within the Basin of the Laurentian Lakes.* *By* Professor W. H. Hobbs.

With the substitution of the method of precise levelling for the aneroid and the hand-level in the study of the abandoned shore-lines of the great lakes, a new epoch has been inaugurated. It now becomes possible to correlate the observations with some measure of assurance, and thus to extend the chapters of the Post-Wisconsin history of the lake region. Generally accepted views concerning the recent tilling of the province are shown to require considerable modification, and prophecies relating to the time of future changes of drainage fall away.

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6. *Report of the Geological Photographs Committee.*—See Reports, p. 245.

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7. *Report on the Erratic Blocks of the British Isles.*—See Reports, p. 242.

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8. *Note on Casts of Dinosaurian Footprints in the Lower Oolite at Whitby.* *By* Harold Brodrick, *M.A.*

The two footprint casts found at Saltwick, a small bay to the south of Whitby, were on blocks of oolitic sandstone which had fallen from the cliff above, so that it is not possible to determine their exact horizon; they must, however, have been within 150 feet of the bottom of the oolites of that district. Both casts are those of the footprints of a three-toed creature, and are similar to those of the iguanodon of the Wealden beds, although on a smaller scale. The first of the Saltwick casts indicates a foot with three functional toes, arranged in the form of a broad arrow; the greatest length is 18 cm., the palm being 6·5 cm. in length, thus giving a length to the middle digit of 11·5 cm. The side digits were about 9·5 cm. in length. The cast is formed of a very fine-grained sandstone, and fortunately the whole of the cast is shown, although it has suffered somewhat from weathering. The second cast seems to represent the footprint of a slightly smaller specimen, and is composed of a rather coarser sandstone; unfortunately the ends of the digits have been broken, so that it is not possible to give exact measurements. The general shape is the same as the first, but the palm is 5 cm. long, while there is a deep corrugation across it as if the creature had a loose fold of skin under its foot. The total length is 12·5 cm., but it is probable that the digits were really a little longer than now shown. On the same slab, and slightly

[1] See, further, Anderson, Report, Part II., *Phil. Trans.*, Series A, vol. 208, pp. 275–300. Flett, Petrology, *ibid.*, pp. 304–333.

overlapped by this cast, is the cast of a smaller footprint, similar in form but only 4 cm. in its greatest length; this may represent the footprint of a still smaller creature, or may be the cast of the manus of the same one. In both cases the impression is deepest at the heel, that of the first being 2·5 cm. deep and the second 2 cm. There seems to be no trace of webbing. As far as I have been able to ascertain, no footprints of this kind have been found in the lower oolite of England, and I am unable to find any reference to such a find in any other part of the world.

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9. *Sixth Report on the Fauna and Flora of the Trias of the British Isles.*—See Reports, p. 269.

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10. *Report on the Faunal Succession in the Carboniferous Limestone (Avonian) of the British Isles.*—See Reports, p. 267.

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11. *Dopplerite from Sluggan Bog, Co. Antrim.* By R. WELCH.

This curious jelly-like substance was discovered in a co. Antrim bog by Mr. Robert Bell, of the Belfast Naturalists' Field Club, a few years ago. The bog is an old cutaway one, and was formerly about 11 feet deeper than at present. The dopplerite occurred as a vein about 3 inches thick about 7 feet from present surface, in the black dense lower peat. It is very slightly elastic under pressure, but breaks away with a jet-like fracture under tension. It contracts very much in drying, and becomes much like jet in colour, fracture, and lustre. Irish observers in the past have noted a jet-like substance in peat without recognising what it was, but Mr. R. Moss, the secretary of the Royal Dublin Society, did so when the first specimens found by Mr. Bell were sent to him. Mr. Moss, in an article in 'The Irish Naturalist' for August 1903, states that it contains in the dry state about 70 to 73 per cent. of humic acid, and that may be regarded as the nearest approach to humic acid occurring in Nature. Since this appeared I have found it in a bog near Cookstown, co. Tyrone, where the peats cut from the turf saturated with dopplerite dry almost as hard as a brick. It is perhaps much more common than is supposed, but is probably seldom separated out in such thick masses as Mr. Bell finds in Sluggan Bog. Mr. Arthur Stelfox, another member of the Belfast Naturalists' Field Club, has noticed it in the West of Ireland. It was first discovered in Germany by Herr Doppler, an inspector of mines, about fifty years ago.

TUESDAY, SEPTEMBER 8.

Discussion on Mountain Building.

Professor J. JOLY said: Of the many features which recent investigations into mountain structure had revealed, the overlap of the upper recumbent folds upon the lower in such a way that the uppermost folds were of greater span than those beneath, was one of the most characteristic and at the same time one of the most difficult of explanation upon existing views. The notion that a horst (or horsts) might be responsible for such a structural feature laboured under the objection that at the depths at which we must suppose the horst located, the temperature must be almost certainly one at which siliceous rock-masses would be highly viscous and not capable of playing the part assigned.

However, an explanation of the phenomenon appeared to reside in this very condition of viscosity, for it would follow that, upon the first development of folding, those synclinal parts of the folds which became depressed into the zone of high temperature would find themselves unacted upon by movement of translation, seeing that the medium around them would be capable of exerting hydrostatic effects only. These effects would doubtless result in the bulging and elevation of the accumulating folds above, but could not result in translatory horizontal motion in one direction more than another.

This hydrostatic condition, however, must gradually give place in an upward direction to conditions of rigidity under which the compressive forces would displace the folded strata. In this matter the physical properties of calcareous strata must play a part. Such rocks would not assume a state of plasticity as a thermal effect so readily as siliceous materials, while possessing an inherent plasticity of a crystalline character, allowing of folding and bending under long continued stress.

If the process of folding was followed through its stages:—the first formation of simple anticlines and synclines; the overthrow of the anticlines of these folds under the directed stresses in the crust; their displacement in the direction of the translatory force while the extreme depths of the synclines remained comparatively unaffected by translatory horizontal movements; and it be borne in mind that the upper and cooler parts of the accumulated mass being the more rigid must partake most fully of the translatory displacement, it would be found that the 'déferlement,' described by M. Lugeon, must arise as the inevitable result.

In support of this view the speaker had made calculations of the temperature which must be attained under such a depth of material as Professor Schmidt of Basel had assigned to the accumulated folds above the Simplon region. This was still nearer the surface than the position of the roots of many of the recumbent folds. If sufficient time were permitted for radioactive heat to accumulate, there must arise a temperature of from 800° to 1000° at a horizon now approximately coinciding with the mean height of the Alps. The assumption of a viscous temperature at the horizon of the synclinal parts of the folds was, therefore, in the highest degree probable, even if the events took place within a period too short to permit of the equilibrium radioactive temperature being attained.

Sir ARCHIBALD GEIKIE remarked that the term 'mountain' had rather a vague signification, but that from the geological point of view it included two main types of structure. In the first place, and most appropriately, it was applied to chains which, like the Alps, have been ridged up by plication of the terrestrial crust; in the second place, it was often also used to describe the results of the prolonged denudation of large tracts of ground in which thick masses of marine sediments have been elevated into land without serious displacement of their original approximate horizontality. The ultimate condition of these upraised plateaux might be such a network of lofty and rugged ridges and deep valleys as almost to rival those produced by the plication of the crust. The cause of the uplift of such plateaux was one of the moot problems of geology. Possibly some of the suggestions put forward in the President's Address might ultimately furnish its solution.

With regard to mountain chains due to deformation of the crust, opinion had greatly varied as to their structure and the causes that gave rise to them. The speaker gave an outline of the history of the investigation of the subject, and remarked that it was now generally admitted that such chains were produced, not by vertical uplift, or by what used to be called 'volcanic' energy, but by tangential movements connected with the earth's secular contraction. The extent to which these movements had plicated rocks had been admirably illustrated from the Alps by Heim. Marcel Bertrand, Rothpletz, Schardt, Schmidt, Lugeon, and others had shown how the folds had been drawn out and piled over each other. These flattened folds had not infrequently been ruptured, as so strikingly displayed in the north-west of Scotland, and had been pushed over each other, so as to bring up some of the older rocks and leave them lying for many miles above the younger formations.

The general principles of mountain structure had now been fairly well made out, but there were still many questions to which no definite answer could yet be given. Thus we had no means of deciding whether the plication was rapid or slow, or whether it might not still be going on. Delicate geodetic observations might determine, in the case of the Alps, for instance, whether the frequent earthquakes of that chain, which pointed to slipping along lines of fracture, were accompanied by movements of uplift or of depression. Another question which opened out a wide field for observation was the determination of the successive periods of disturbance to which any given mountain range owes its origin. It would be interesting also to ascertain the conditions under which volcanic vents are at last opened along a chain of mountains. As investigations advance doubtless many new features of structure may be expected to arise, which will engage the attention of geologists for many generations to come.

Professor SOLLAS remarked that all doubts he might have felt as to the existence of recumbent folds on the scale asserted by French and Swiss geologists had been dispelled by a careful examination of the pre-Alps, made under the guidance of Professor M. Lugeon. The structure was obvious and the interpretation was confirmed by the superposition of the Piedmontese on the Helvetian facies. The question had been much simplified by the new views advanced by the President, which completely explained one of the greatest difficulties of the subject. The geometrical properties of the fold were worthy of some consideration; it was obvious that the volume within the fold increased with its growth up to a stage at which the middle limb was nearly vertical, and up to this point the internal pressure diminished. Beyond it, further advance of the hinder limb produced a flattening-out of the fold and a diminution of internal volume, which led to the extraversation of molten material from the region of the hinder limb, *i.e.*, on the concave side of the mountain arc. When the three limbs of the fold were reduced to parallelism a second fold might arise behind it, to pass through the same stages, and this might be repeated several times. When the middle limb was pushed past the vertical the conditions would render an independent movement of the hinder limb very possible, and this might advance as a sheet over great distances; superimposed sheets, such as occur in the Alps, might thus be formed. The piled-up folds would, as the President had shown, blanket over the deeper region so effectually that the geotherms might rise through a great interval. A highly heated region beneath the mountain folds might therefore be expected, and this might account for the lower value of gravity met with in the neighbourhood of mountain chains. The approximation of remote areas brought about by folding involved the transference of viscous material from one region to another; bulging up, though it occurred, would not account for the whole of this. It might travel long distances. The thrusting which built up the Alps and Carpathians was felt in the British Isles, where it produced the posthumous folds of the Weald and splintered the crust of Scotland and the North of England, as well as parts of Ireland. The cracks then produced afforded a passage for underlying lava, which itself might also have originated under the Alps. The upward growth of a mountain chain possibly represented only a balance of movement, for a subterranean draining-off of molten material would produce a continual lowering of the base.

Given the deformational figure of the earth, the position of the mountain chains, on Professor Joly's theory, follows from it, since they will arise where sediments are deposited at the limits of land and water. There is much indeed to suggest that the mountain chains of the past have thus originated as a consequence of the varying influence of the differential harmonics elicited by Professor Love.

Professor COLE urged, as Sir A. Geikie had done, the importance of keeping in view the formation of mountain-masses by block-uplift as well as by overfolding. The early geologists, such as Scrope, recognised recumbent folds when they attributed mountains to the vertical upthrust of igneous cores and the slipping away of sediments on either side. Gravitational sliding being well recognised in existing theories of Alpine structure, it became important to ask if the older views were really wrong, and perhaps, with E. Reyer, we ought to reconsider the whole theory of lateral thrusting as against that of superficial downsliding. The speaker compared the curved front of a mountain chain in process of formation with the advancing front of a land-slide, and asked for a tolerant examination of Ampferer's view of the *Untergrund* or sub-crustal region as the layer that induces superficial flow by dragging the solidified crust upon its surface. Carrying the question into still more speculative regions, he asked if the cause of epochs of mountain-building on the earth as a whole might not be due to some primordial periodic change of temperature in the interior, inherited from the time when our planet formed part of what we call a variable star.

The following Reports and Papers were then read:—

1. *Third Report on the Crystalline Rocks of Anglesey.*

See Reports, p. 283.

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2. *On the Finding of Silurian Beds in Kent.* *By* W. WHITAKER, *F.R.S.*

A boring has lately been made, to a great depth, at Messrs. Curtis & Harvey's works, on the Thames Marshes at Cliffe, for the purpose of getting a supply of water, firstly from the Chalk and then from the Lower Greensand. It has failed in this, the water from both formations being too salt to be of any use; but it has succeeded in adding a geologic formation to the Kentish list, and that the oldest yet found in the county.

Details of the section will be given in a forthcoming Geological Survey Memoir on the Water-supply of Kent. It should be noted that the division between some of the formations is doubtful, but any error from this cause is immaterial in the following abstract:—

Alluvium and River Gravel	77	1074 feet.
Upper, Middle, and Lower Chalk	656 (or more)	
Gault	208 (or less)	
Lower Greensand	96 (or less)	
Dark grey clayey rock	37 (or more)	

Nearly the whole of the Chalk has been pierced, the topmost part only being absent. The thickness given to the Gault is a little more than in the borings at Chatham, Frindsbury, and Strood eastward, and still more than at Erith (Crossness) westward. The thickness given to the Lower Greensand is also more than at Chatham, whilst at Erith there is none of this formation.

The chief interest of the boring, however, lies in the facts that the floor of the older rocks, which has been proved in many places in Kent, was reached at a level of about 1,030 feet below Ordnance Datum, and that the Palæozoic formation found is of Silurian age, nothing older than Devonian having been hitherto recorded from the deep borings of the county, and that only at Brabourne, unless the red rocks at Crossness should turn out to be of like age.

The proof of the Silurian age of the lowest beds is given by the occurrence of fossils at the depth of 1,063 feet, *Atrypa reticularis* and *Plectambonites* having been determined at the Palæontological Department of the Geological Survey by Mr. H. A. Allen, from samples of the cores sent by Mr. Baldwin Latham. There are traces of other fossils.

The practical value of the boring is that it puts a northern limit to the Kent coal-field in its neighbourhood.

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3. *On a Case of Thrust and Crush Brecciation in the Magnesian Limestone, Co. Durham.* *By* DAVID WOOLACOTT, *D.Sc., F.G.S.*

Along the two miles of cliff between South Shields and Marsden the breccias that form so marked a peculiarity of the Magnesian Limestone of north-east England are best exposed. The rocks seen are the Yellow Sands, Marl Slate, and Magnesian Limestone, but the exposure of the first two are too small for the effect on them of the thrust, here described, to be observed. The limestone, although much disturbed, has a general low dip to the south. It consists of a series of rocks of different flexibility, rigidity, brittleness, and compressive strength, and the uniqueness of the section is due to the action of a thrust from the north, which has caused some of the beds to move laterally upon the others, with an associated production of folding, minor-thrusting, and fissuring, and a consequent development of dynamic brecciation.

In Frenchman's Bay the Lower Limestone (40 feet thick) is a brownish-yellow, regularly-bedded rock of relatively high compressive strength and rigidity. Its lower layers are gently folded, but its top layers are considerably disturbed, being fractured, tilted-up, and laterally displaced. Resting on this is about 50 feet of Brecciated Limestone, consisting almost entirely of a cemented mass of broken fragment, which have here and there been dissolved out from the cementing matrix, the rock becoming cellular. In places the bedding, unfolded but fractured, is still preserved. It was originally a finely laminated granular limestone, and is of low rigidity and compressive strength. Experiments performed by Dr. Morrow give the following results: Compressive strengths (tons per square inch to break rock), Lower Limestone, 5·7 tons; Brecciated Bed (lower middle), 1 ton.

The junction of the Brecciated Beds with the Lower Limestone is a thrust plane, which does not always coincide with the line of demarcation between the two strata; and the disturbance of the upper layers of the latter rock, together with the smashing up of the former, is due to the thrust movement.

The Brecciated Beds occupy the top of the cliff for over a mile. Their upper surface, which is seen at the north end of Marsden Bay, is very irregular and hummocky, the breccia having been forced up into the base of the beds above. These consist of about 200 feet of rock differing much in flexibility and compressive strength (specimens tested vary from 1 ton to 3·7 tons per square inch). They have been thrust against a horst, and consequently folding, thrusting, and dynamic brecciation has taken place. The flexible beds have been deformed without being much broken, while a harder, more brittle, wedge-shaped limestone has been highly brecciated. The latter has also had a coarse cleavage structure impressed on it, and part of it has been torn off and thrust into the beds above. Breccia gashes and vertical fissures filled with breccia, which has fallen into them, occur on both sides of this folded and broken area. The amount of lateral displacement at this point is difficult to estimate accurately, but it has probably been about 100 yards, and the experiments indicate that the magnitude of the thrust was about 300 tons per square foot.

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4. *Well-water Supply of the North-Eastern Sudan.* *By* G. W. Grabham.

In the development of the north-eastern Sudan, water-supplies are of supreme importance, and the Government has already expended large sums of money in sinking wells along the railways and roads.

Artesian conditions have not been met with, and the supplies are dependent on the rainfall and local geological conditions. There are two distinct rainfall systems; one affects the plains during the summer months, while the other rains occur during the winter months, and are confined to the Red Sea coast.

The country is formed of crystalline rocks, and on the uneven surface of these rest the Nubian sandstone, &c. The surface deposits vary according to the climate and the underlying rock. In the north the conditions are similar to those described by Mr. Ferrar, but to the south, where the rainfall is greater, the plains are covered by a blanket of 'cotton soil.' This soil is very fine grained and absorbs a great deal of water during the rains. In the dry season the moisture evaporates, and the surface becomes fissured with deep wide cracks. A very thin layer of this soil prevents the rainfall from reaching any underlying deposit, which might otherwise become saturated.

In the northern area the rainfall does not exceed four inches per annum, except among the hills bordering the maritime plain. The valleys contain a great deal of 'valley fill,' which at once absorbs the water, preserves it from evaporation, and good quantities can be obtained from wells.

In the 'cotton soil' area water is only found where hills of decomposable rock break the impermeable layer, at the same time forming a porous mass which holds the water.

Where sandstone, and not crystalline rock, underlies the surface deposits, the underground water is, perhaps, mainly supplied by seepage from the rivers, and is not dependent on the ability of rain-water to penetrate the surface deposits. Though the water-level is often more than 100 feet below the surface, water may be obtained for some time after the rains from shallow holes made in the beds of khors, and it does not appear that an impermeable substratum is necessary to maintain this upper zone of saturation.

5. *Contemporaneous Erosion in the Lower Series of Coal Measures of the Bristol Coal-field.* *By* H. Bolton.

6. *Report on the pre-Devonian Beds of the Mendips and the Bristol Area.*—See Reports, p. 286.

7. *On a Fossil Reptile with a Trunk from the Upper Karroo Rocks of Cape Colony.* *By* Professor H. G. Seeley, *F.R.S.*

In all the reptiles from South Africa hitherto made known the external openings of the nostrils are divided, with the possible exception of the genus *Gorgonops*—a Theriodont reptile, in which the nasal openings are terminal and have the aspect of the figure ∞ compressed from above downward. The animal now described belongs to the Bidental or Dicynodont type, in most of which the nares are at the sides of the face, as in existing lizards, and are sometimes far away from the end of the snout, as in *Ptychognathus*. The animal is shown to belong to this group by having two large lateral tusks or canines, like all the genera of the family, and by the palate making no divergence in plan from that of Dicynodon. The palate forms a regular arch from side to side. Above it is the slightly reniform nasal opening, 4½ inches wide and an inch deep. The aperture is unlike that in the skull of a tapir, and closely similar to that in the skull of an elephant to which the trunk is attached. Its borders are smooth on the inner side. At the bottom of this excavation the cavity contracts to half the width, but is not divided into two nostrils, though the vomer appears to rise, so as to indent the base of the nasal passage. The author regards the teeth of Dicynodonts as having been used, probably, to pull down structures like ant-hills formed by the white ants, and finds in the narrow groove between the rami of the lower jaw in Dicynodonts a channel which carried the extensible tongue adapted for an insectivorous diet. In this case the large teeth were equally adapted for tearing open ant-hills. But the remarkable evidence of a trunk indicates that the head was extended in front, by a soft flexible part which would give it a functional elongation, like that of the Orycteropus or Myrmecophaga. The aperture which indicates the trunk is so like that in the skulls of elephants as to suggest a trunk of a similar kind, and only differs in the absence of any depth of bone between the mouth and the nose such as in elephants carries teeth. The skull is 13 inches long, and appears to have been 14 inches wide behind. It is not perfect, and no other part of the skeleton is known. It is proposed to name the fossil *Kannemeyeria proboscoides*. It was found in 1895 by Dr. Kannemeyer, near Burghersdorp.

8. *On Distinctions in Dentition between the Fossil Reptilia classed as Cynodontia and Gomphodontia. By* Professor H. G. Seeley, *F.R.S.*

These two divisions of the Theriodont reptilia appear to be more definitely distinguished by dental conditions than was evident when they were defined in 1895. The Gomphodontia are those animals which resemble mammals in the unworn and worn conditions of the grinder teeth and in the diastema which exists between the canine and the first molar. The author found thirteen molar teeth in the mandible of *Gomphognathus Kannemeyeri* which are similar to each other. In *G. Polyphagus* only nine molar teeth were found, but indications exist of at least four minute pointed conical teeth in advance of the molars, all of which appear to have the crowns broken, and their removal lengthens the diastema. The fragment of a mandible figured in illustration of Tritylodon has similar teeth in the diastema apparently worn level with the jaw during the life of the animal, and now distinguished under the specific name *dimorphodon.* These species are separated from *Gomphognathus* as *Diastemodon.* The teeth in the diastema are regarded as milk molars, which are never shed, but cease to be effective by losing their crowns.

There is no evidence that any Gomphodont reptile has teeth upon the palate, on the maxillary, palatine, pterygoid, or other bone, and in this condition they resemble mammals.

The Cynodontia, in Ælurosaurus, a carnivorous type with small, sharp, conical molar teeth, are already known to have teeth upon the palate; but the specimens have had the mandible closed upon the skull, so that the structure of the palate is not seen. The author has received two specimens from Dr. Kannemeyer which give a better knowledge of the palate in the genus Cynognathus. In one specimen the palatal plate of the maxillary bone carries on its inner third a strong wedge of dental armature. The individual teeth form several parallel rows blended together in the manner of Hyperodapedon. This dental mass is blended with the maxillary bone except in front, where one plate is lost from an empty socket. The crowns are but slightly elevated, of ovate form carrying one or two elevated lines, and sometimes a few granules.

The second specimen is crushed, and the species is not yet determined. It shows that the maxillary armature of crushing-plates met in the medial line of the palate. It also shows that an armature of crushing-teeth forming a flat wrinkled enamelled surface was developed upon the edge of the palatine bone, so as nearly to surround the posterior nares. This structure is entirely behind the maxillary plate instead of being parallel to it, as in Hyperodapedon. The maxillary plate has now been partly uncovered in the type *Cynognathus crateronotus,* and shows that the palate carries teeth like those in the new specimens. The alveolar teeth are so typically carnivorous that these palatal teeth are unexpected structures.

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9. *Report on the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, &c.*—See Reports, p. 296.

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10. *Interim Report on the Correlation and Age of South African Strata, &c.*

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11. *Report on Topographical and Geological Terms used locally in South Africa.*—See Reports, p. 286.

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12. *Report on the Exact Significance of Local Terms.*

Section D.—ZOOLOGY.

President of the Section.—S. F. Harmer, M.A., Sc.D., F.R.S.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address:—

The British Association meets this year for the fourth time in Dublin. The last occasion was just thirty years ago, when Sir William Flower presided over Section D, while Professor Huxley was Chairman of the Department of Anthropology, at that time not raised to the dignity of a separate Section, and Sir Wyville Thomson was President of Section E. The last Dublin meeting was fortunate in having among its officers men who have left an enduring mark on Zoological science.

I can hardly come to the more immediate subject of my Address without referring to the death, on March 9 last, of Henry Clifton Sorby, who had been a member of the Association for nearly fifty years. Dr. Sorby was President of Section C in 1880; but although he does not appear to have presided over Section D, many of his sympathies were with Zoology. He belonged to a type which is becoming almost extinct with the increasing specialisation of science, having done pioneer work in more than one branch. His interest in Chemistry was no doubt responsible for his having taken up the subject of the pigmentation of animals, by his researches on which he is probably best known to Zoologists. During recent years he had devoted particular attention to the study of the marine fauna of East Anglia.

According to the popular estimate, Zoology is regarded as the branch of science that has perhaps the least reference to the details of practical life. The importance of the applications of Chemistry, Physics, Geology, Botany, and Physiology to questions which involve the welfare of the human race is obvious and universally admitted. But pure Zoology is often supposed to be a study of merely academic interest, and its relation to the practical concerns of mankind is not always apparent. It is no doubt true that many of the investigations undertaken by Zoologists are of a highly special nature; and yet when the sum total of the results achieved by workers in this science is estimated it will be found that the contributions of Zoology to the common stock of human knowledge are by no means of restricted application.

There is no conception which has more profoundly influenced thought in all branches of knowledge than the idea of organic evolution, in the development of which Zoology has shared the honours with its sister-subject, Botany. The present summer has seen a memorable event in the celebration by the Linnean Society, on July 1, of the fiftieth anniversary of the communication to that society of papers, by Darwin and Wallace, which revolutionised the whole of Biology. There can surely have been few occasions when the commemoration of the jubilee of an epoch-making discovery has been attended by the man whose work was thus recognised. I am sure that I am expressing a unanimous feeling in saying that the award of the first Darwin-Wallace medal on that occasion to Mr. Wallace in person was a source of deep gratification to all men of science, and that the presence at the same meeting of others whom all Biologists must regard with peculiar respect gave the occasion a perfectly unique character.

The present century has seen a remarkable development of the study of the problems of heredity and variation, largely as the result of the interest awakened in the resuscitation of Mendel's experimental work from the oblivion in which it had remained for so many years, though the general problem is being attacked concurrently by investigators who attach more importance to the statistical method of study. Professor Bateson, who has given the name 'Genetics' to the experimental study of heredity, chose the advances made in that branch of Biology up to 1904 as the subject of his able Address to Section D in that year. Some of the more recent conclusions of the workers in Genetics are to be discussed by this Section during the present meeting. It cannot be doubted that an accurate knowledge of the principles of heredity is destined to exert a marked influence on the practical concerns of humanity.

The study of diseases which are due to parasitic Protozoa has made striking progress during the last few years. Protozoology has become a distinct branch of Zoology, represented by its own journals and its own professors and lecturers, while it can command the resources of the schools of tropical medicine where researches are being carried on from which great benefits to humanity may be anticipated. Malaria, sleeping-sickness, yellow fever, and the numerous diseases of domestic animals due to parasitic Protozoa such as *Trypanosoma*, *Spirochæta*, and *Piroplasma*, are some of the complaints which are now recognised as the objects of Zoological study. Most of these diseases are transmitted by blood-sucking insects and arachnids, an accurate knowledge of which has become a matter of pressing practical importance.

The history of Protozoology affords a complete vindication of the importance, even from a utilitarian standpoint, of conducting scientific investigations for their own sake, even though the likelihood that they will ever have any practical bearing may not at first be apparent. Some years ago it would have been generally supposed that the study of Ticks was a case of this kind, and that it could at most be of interest to the special students of the Arachnida. How far such a view would have been from the truth is well known, but we are suffering now from the comparative neglect of this group of animals in the past. There is still no satisfactory monograph by the aid of which the species of Ticks can be discriminated, and there are few Zoologists who would be prepared to express an opinion with regard to the determination of even those species that are the commonest and the most injurious. While it is clear that the investigation of the Arthropod carriers of parasitic Protozoa is essentially a Zoological question, it is equally true that the elucidation of the parasites themselves is largely dependent on the results that have been achieved by Zoological investigators who have worked without any thought of a practical outcome. The late Professor Schaudinn, to whom we owe so many brilliant results in the study of the Protozoa, commenced his investigations from the Zoological side, and continued them in their applications to preventive medicine. It is generally admitted that the study of many of the tropical diseases can only be carried on by means of a due co-ordination between Zoological and Medical methods of inquiry.

As a further instance of the manner in which Biological science may react on other studies, I may mention the interesting theory which has recently been developed by Mr. W. H. S. Jones,[1] to the effect that the decay of the ancient civilisations of Greece and Rome was largely due to the introduction of malaria into those countries.

I can do no more than allude to Economic Entomology, a subject which has at present received but little official support in our own country, although its importance is fully recognised abroad, particularly in the United States of

[1] *Malaria: A Neglected Factor in the History of Greece and Rome.* Cambridge (Macmillan & Bowes), 1907.

America, where large organisations are devoted to the combat with the insect enemies of agriculture. We are fortunately spared some of the worst of the foes of vegetation which devastate other lands. But many of our cultivated plants suffer severely from the ravages of insects and arachnids; and it is perhaps not too much to hope that more systematic measures will some day be taken in this country to disseminate the knowledge by which this injury to agriculture may be minimised.

As a last illustration of the way in which Zoology comes into relation with practical matters, I may allude to the question of fishery investigation. Although much remains to be done in this connection, the importance of purely scientific work has been to some extent officially recognised. The Board of Agriculture and Fisheries in England, the Scottish Fishery Board, the Fisheries Branch of the Department of Agriculture and Technical Instruction for Ireland, and other organisations which are mainly or entirely supported by private funds, are in part devoted to the interests of the fishing industry. The Government have latterly participated in an international investigation of the North Sea, as the result of which many interesting facts have been recorded with regard to the life-histories of food-fishes, their migrations at various periods of life, the age at which they become sexually mature, and the nature of their food. These are questions that demand study by experienced Zoologists; and the interrelations of food-fishes and the organisms on which they subsist or with which they come into competition are so complex that a full study of the entire marine fauna appears to be a necessary preliminary to the elucidation of the questions of immediate practical utility.

I have tried to indicate that Zoology is a subject that has important relations with the practical concerns of mankind. But in Zoology, as in other branches of science, the principal advances have been made by investigators who have studied it for its own sake, without thought of the practical outcome. It would undoubtedly be a misfortune should an entirely utilitarian spirit become dominant in the pursuit of science. In the full conviction of the truth of this statement I venture to invite your attention to certain questions connected with the Polyzoa—a somewhat neglected group of animals which I do not profess to be able to connect in any direct way with practical matters. In choosing this subject I have been influenced by the belief that it is well for the President of a Section to speak on matters of which he has had practical experience.

During the course of my studies on the Polyzoa I have been conscious of the existence of many unsolved problems and difficulties, some of which are connected with the functions, distribution, and variations of certain remarkable appendages known as 'avicularia' and 'vibracula.' Although the facts bearing on the significance of these organs are familiar to specialists only, they appear to me capable of throwing light on questions of general Biological interest, particularly in connection with variation in animals that increase by budding.

The statement has often been made, as the result of a theoretical conception of the physical basis of heredity, that the asexual method of reproduction gives rise to little or no variability. Although there are many reasons for doubting the validity of this conclusion, it may be well to state at the outset that the Polyzoa, which are without exception characterised by increasing in an asexual manner, show a high degree of variability in the individuals thus produced. So much is this the case that the want of fixity of type which results from the tendency to vary renders the definition of species particularly difficult in this group of animals.

Meeting as we do at Dublin there is a special appropriateness in discussing the Polyzoa, as a tribute to the memory of a distinguished Irish naturalist, J. V. Thompson, to whom we owe not only the name Polyzoa, but also the first clear conception of what these animals really are. In the fifth memoir, published at Cork in 1830, of a short but brilliant series of papers,[1] Thompson was the first to demonstrate the essential nature of the differences between the Polyzoa and the other 'Zoophytes' with which they had previously been classified. G. J. Allman, who at a later period did so much to throw light on the structure and natural

[1] *Zoological Researches and Illustrations.*

history of these animals, particularly by his classical monograph on the Fresh-water Polyzoa,[1] was also an Irishman, who was born at Cork, and for some years held the professorship of Botany in the University of Dublin. Thomas Hincks, another worker who was pre-eminent for his knowledge of the Polyzoa and for the importance of his researches in this field, held professional appointments both at Cork and at Dublin for several years.

The Polyzoa are a group which is quite unknown to most persons who are not Zoologists. Before coming to my special subject, the variations of the avicularia, I may for this reason, perhaps, be excused for attempting to explain what the Polyzoa are like, and, in particular, what are the nature and functions of the structures we have to discuss.

The Polyzoa are a class of aquatic organisms of world-wide distribution and including a large number of species. They occur both in fresh water and in the sea, and the marine forms are found from between tide-marks to the deepest abysses of the ocean. Some of the species are among the commonest objects of the sea-shore, and others may be obtained in numbers by the use of the dredge or trawl. They often occur as delicate encrustations, usually calcareous, on plants, stones, or shells; or they may assume the appearance of sea-weeds, corals, or hydroids. Although most of them are of comparatively small size, they are usually large enough to be recognised by the naked eye, while the largest of them reach a diameter of a foot or two.

The Polyzoa are always colonial animals, the colony consisting of a number of individuals which are in organic connection with one another, though they may appear at first sight as a series of isolated units. Each of these units consists of a body-wall, which is usually calcified and is termed the 'zoœcium,' since it was at one time supposed to constitute a sort of house for a zooid known as the 'polypide.' The idea of a dimorphism of individuals expressed by this nomenclature is no longer accepted, but the terms themselves are still conveniently employed for descriptive purposes. The polypide consists in reality of the visceral mass of the zoœcium, together with the series of ciliated tentacles which are used for the capture of food. The tentacles are protrusible, but are commonly found retracted into the interior of the zoœcium, in which condition they lie in a thin-walled introvert or 'tentacle-sheath,' which opens to the exterior by an 'orifice' in the wall of the zoœcium. In the sub-order Cheilostomata, to which my remarks will principally refer, the orifice is closed, during the retracted condition of the polypide, by a chitinous lid or 'operculum.'

In the great majority of cases the colony is inaugurated by the fixation of a free-swimming larva, which has been produced from an egg by the ordinary sexual method. On the completion of its metamorphosis the larva becomes the first zoœcium of the colony, and is then known as the 'ancestrula,' a term introduced by Jullien to signify that it is the ancestor of the future colony. In a large number of species belonging to the most diverse genera of Cheilostomes the ancestrula has a certain definite character which appears to have no relation to that of the individuals to which it gives rise by budding. The type of ancestrula in question has a striking resemblance to a single zoœcium of many of the species of the existing genus *Membranipora*, and is characterised by having a series of marginal spines which surround a region closed by a chitinous membrane, at one end of which is situated the operculum. That this form of ancestrula has a definite significance is indicated by its wide occurrence among Cheilostomes and by the fact that the same cannot be said of any other form of ancestrula, and is confirmed by the palæontological occurrence of *Membranipora* as one of the earliest genera of Cheilostomata.

The ancestrula gives rise by budding to daughter-zoœcia, which usually assume from the first the characters proper to their species. In the growing colony the formation of new zoœcia takes place at the expense of a marginal zone, which contains the tissues concerned in the bud-development. Omitting the consideration of special regenerative processes which may take place, a zoœcium

[1] Ray Society, 1856.

which has once been constituted at the growing margin of the colony does not, as a rule, possess the power of giving rise to new zoœcia, although it commonly has the faculty of producing sexual cells from which free larvæ may develop.

In the majority of the species of Cheilostomata many of the individuals of the colony have the form of the so-called avicularia. An avicularium is characterised by possessing a chitinous 'mandible,' which can be closed with great force by strong occlusor muscles, the organ being thus essentially of a prehensile nature. There can be little doubt that the mandible is a modification of the chitinous operculum which closes the orifice of the tentacle-sheath in Cheilostomata. It thus follows that avicularia are restricted to this particular division[1] of the Polyzoa. In the avicularium the operculum has become relatively and often absolutely enlarged, and its muscles have become more powerful than those of the unmodified zoœcia. The internal viscera have, as a rule, disappeared, and there are thus neither tentacles nor alimentary canal. The body-wall, or zoœcium, has become a case which contains the muscles, while part of it has been prolonged into a beak-like structure or 'rostrum,' which, with the chitinous mandible, constitutes the prehensile mechanism.

In *Bugula* and its allies the avicularium has the form to which its name refers, and has a striking resemblance to the head of a bird like an eagle or vulture. This resemblance is due, not only to the general form of the structure, but also to the hooked and beak-like shape of its rostrum and to the narrow neck by which it is connected with the zoœcium on which it is borne. The avicularia of *Bugula* have considerable powers of movement, and in the living condition they may be seen to bend backwards and forwards on their flexible neck, their range of action being thus considerably enlarged. The mandible is ordinarily held wide open, but it closes with great force when some foreign object is placed between the jaws. An avicularium which has in this way seized a small worm, for instance, is known to be able to retain its capture for many hours, in some cases for more than an entire day.

In the majority of Cheilostomata the avicularia are, however, not stalked. They occur scattered over the colony in a considerable variety of positions, and usually appear as appendages rigidly connected with the walls of the zoœcia.

More than one attempt has been made to explain the functions of the avicularia. The distribution of these organs indicates, I think, that the simplest and most obvious explanation is the correct one—namely, that, like the pedicellariæ of Echinoderms, they are defensive organs. The ordinary unmodified opercula probably have the same function in many cases; and if account be taken of the fact that the avicularium is morphologically a modified zoœcium it becomes easy to understand that the defensive office of the opercula has been made more efficient in specially modified zoœcia which concentrate their energies on this one function alone.

A casual inspection of a number of Cheilostomes taken almost at random reveals the fact that the avicularia are specially common in the immediate neighbourhood of the orifice of the tentacle-sheath and of that of the 'compensation-sac.'

This is a thin-walled cavity which in a considerable proportion of the Cheilostomes opens to the exterior at the proximal border of the operculum. Its principal function is to permit protrusion and retraction of the polypide to take place, since in a zoœcium with completely rigid walls the act of protrusion could not occur if the temporary removal of structures of considerable size were not compensated for by the admission of water into the space included by the rigid body-wall. At each movement of protrusion, therefore, a volume of water corresponding with that of the protruded organs is admitted into the compensation-sac, the dilatation of which, by means of radiating muscle-fibres, is the cause of the protrusion; and is again evacuated when the polypide is retracted. These alternate actions of filling and emptying the compensation-sac with water from

[1] It may be noted that Palæontologists have described structures which they have regarded as avicularia in Polyzoa which do not belong to the Cheilostomata.

the outside are probably of importance in the respiration of the animal. The advantages of having avicularia in such a position that they can guard the orifice from which the tentacles are protruded and that of the compensation-sac are too obvious to require detailed discussion.

The avicularia probably afford little if any protection against the attacks of the larger foes, such as Fishes, Echinids, and Nudibranch Molluscs, which are said to browse on Polyzoa. But there is one group of enemies against which the opercula and the mandibles are probably particularly effective. These are encrusting organisms, including other species of Polyzoa; and indeed the enemies against which a Polyzoon has to provide are probably in a special degree the members of its own class.

In many Polyzoa which afford large surfaces suitable for the growth of encrusting organisms the older parts of the colony, where the opercula and mandibles are no longer in working order, do actually harbour large numbers of encrusting Polyzoa, Sponges, Ascidians, and other organisms. These are usually absent in the active parts of the colony nearer the growing margins. In these positions the only animals which obtain a footing are such forms as the Infusorian *Folliculina*, adapted by its minuteness to find a place between the defensive appendages, or such organisms as are attached by means of delicate creeping stolons or rootlets that can find their way between the opercula and mandibles without being damaged by them. A branching species fixed by a narrow base may do little harm to a Polyzoon on which it is growing. But the effects of an encrusting species would be different, since the orifices of the colony which is being overgrown would be occluded, and the polypides entirely cut off from the outer world. Although experimental evidence is at present wanting to prove this view, I have little doubt that the avicularia are specially important in preventing the fixation of the larvæ of encrusting species. The larva is of course very vulnerable, and it cannot become the founder of an adult colony unless it can find a secluded spot in which it is safe from undue disturbance during the critical time of its metamorphosis. The avicularia are well adapted by their form for warding off larvæ. Those that have the so-called 'duck-billed' or 'spatulate' form are in many cases large enough to catch or crush a larva without difficulty, while those which have a mandible terminated by a spike-like projection must be even more destructive to the life of any minute organism which is so imprudent as to stray within their reach. In some of the avicularia belonging to this latter type the mandible is strongly compressed along the greater part of its length, and may then assume the shape of a knife-blade, with a sharp cutting edge and a thicker back. The blade shuts down into the calcareous rostrum of the avicularium in such a way that its action may be compared to that of a pair of scissors. It cannot be doubted that this form of avicularium has a high protective value.

In some cases the mandibles or the opercula are toothed. The teeth are specially strong in certain species of the genus *Steganoporella*, where the opercula become most formidable weapons. The large development of the occlusor muscles proves that the closure of these opercula must take place with much force.

The protective value of the avicularia may be illustrated by the distribution of these organs in *Retepora*, the species of which usually grow in the form of a calcareous network, with oval meshes or 'fenestræ' between the branches. These are furnished with an elaborate armature of avicularia, which usually occur in large numbers and in considerable variety of form and size. Some of them are scattered over the front surface, on which alone the zoœcia open, while others occur on the more unprotected backs of the branches, where there are no zoœcial orifices. To guard against an attack from the rear the margins of the fenestræ are frequently furnished with avicularia, among which some are usually of a specially large size, and are well situated to intercept any larva or adult animal that might attempt to pass through a fenestra.

A healthy Retepore is usually completely free from encrusting organisms in regions where the avicularia are functional. One of the few exceptions I have noticed to this rule is specially instructive. In this case a small encrusting

Cheilostome colony is growing near the edge of the *Retepora* frond. The primary individual or ancestrula of the encrusting colony is readily distinguishable, and its position shows that the larva from which it was formed must have attached itself to the growing margin of the Retepore, a region in which the avicularia were not fully formed. Having thus established itself, the colony has succeeded in invading a small region of the adjacent parts where the zoœcia are still vigorous and healthy. A dead *Retepora*, on the contrary, forms a substratum which is well adapted for the growth of various organisms, such as other Polyzoa, Sponges, Hydroids, Compound Ascidians, and Foraminifera.

Although the avicularia are thus effective in preventing the overgrowth of the colony by most of the organisms that might otherwise settle there, there are one or two animals of suitable habit which have succeeded in establishing themselves in the very midst of the defensive works. In species of *Retepora* from the Malay Archipelago[1] I find that a considerable proportion of the colonies are infested by a Gymnoblastic Hydroid of *Syncoryne*-like appearance. The association of this with its host is so intimate that the hydrorhiza becomes completely included in tunnels formed in the calcareous mass of the Polyzoon, where it is, of course, safe from the avicularia. These tunnels, the walls of which are secreted by the Polyzoon, open to the exterior by tubular apertures situated on the margins of the fenestræ and on other parts; and they are so definite in their appearance, and often so regularly arranged, that it might be difficult to believe that they were not a normal feature of the *Retepora* were it not possible to demonstrate their relation to the Hydroid.[2]

There is one other organism which has a definite relation to colonies of *Retepora* in Malay waters. This is *Loxosoma*, a stalked Polyzoon which leads a practically solitary life owing to the fact that its buds break off as soon as they have reached maturity. The *Loxosoma* no doubt succeeds in enjoying a secure existence, even though it is surrounded by avicularia, owing partly to its stalked form and partly to its minute size. It is commonly found in considerable numbers, and often attaches itself in such a way that it projects into one of the fenestræ, where it is as far as possible removed from the dangerous neighbourhood of the avicularia.

We have thus seen that, while the species of *Retepora* are adequately protected against many encrusting or epizoic organisms, there are one or two animals that have succeeded in evading the attacks of the avicularia, which, it must be remembered, are rigidly attached to the colony, and cannot go in search of any enemy that keeps out of their way. The efficient avicularian protection may well be responsible for the fact that *Retepora* is a common and widely distributed genus, flourishing in both shallow and deep water. Not only is it found in large numbers in the most diverse localities, but it has differentiated itself into a large number of species, among which avicularia occur in great profusion and in a great variety of forms. But so soon as the avicularia cease to be active we find that numerous organisms settle on the unprotected branches; and a dead colony of *Retepora* is accordingly usually found to be invaded by numbers of other animals.

One other familiar case may be mentioned illustrative of the means by which a Polyzoon may be protected from encrusting organisms, and at the same time of

[1] The greater number of the facts referred to in this Address have been observed during my study of the Polyzoa collected during the *Siboga* expedition.

[2] It may be noted, as has already been done by Alcock (*Ann. Mag. Nat. Hist.*, ser. 6, x. 1892, p. 207), that many other cases are known in which there is an association between a Gymnoblastic Hydroid and some other animal. The interesting case of the association of a Gymnoblastic Hydroid (*Stylactis*) with a fish (*Minous*) described by Alcock has also been described, more recently, by Franz and Stechow (*Zool. Anzeiger*, xxxii. 1908, p. 752). Another case of the association of a Cœlenterate with a Polyzoon has been recorded by Haswell and by Kirkpatrick, who have called attention to the occurrence of a small 'Actinid' which forms definite cavities in a massive calcareous Cheilostome from Australian waters. There is in this case no satisfactory evidence to show what the Cœlenterate really is.

the success with which certain animals have ignored the defensive works that are effective against ordinary foes. This is the common *Flustra foliacea* of our own shores, in which, although avicularia are present, the defence is provided largely by the numerous stiff spines which make its surface irregular, and thus unsuitable for the growth of an encrusting organism. But certain delicate Polyzoa, such as *Crisia* and *Scrupocellaria,* which are attached by fine rootlets, flourish on this species, their rooting processes being able to adapt themselves to the irregularities of the surface, and to escape the closure of the opercula and mandibles. A Gymnoblastic Hydroid (*Hydranthea margarica*) of a similar mode of growth is also known to occur on healthy colonies of *Flustra foliacea.*

In a large number of erect Polyzoa the colony, or zoarium, assumes the form of a small branching tree-like growth in which, as in *Retepora,* the zoœcia open on one surface only of the branches. The opposite surface is often devoid of any armature of avicularia or vibracula, a fact which at first sight seems opposed to the view that these structures are protective. But I think that in some of these cases the form of the zoarium affords an answer to this objection, since the branches are so crowded that the avicularia of the front surface of one branch are probably quite capable of affording protection to the backs of the nearest branches. It may be noted that *Scrupocellaria* and *Caberea,* in which vibracula occur on the backs of the branches, usually have a much laxer mode of growth than *Bugula,* in which the back is unprotected.

In some other erect species there are no avicularia at all. But here we often find, as in *Euthyris,* that the whole of the frond is covered by an organic membrane, the 'epitheca,' which invests the calcareous parts; and it seems to me probable that this epithecal layer is itself protective. Schiemenz has shown that it is an advantage to certain Molluscs to have an internal shell, since Starfishes can devour Molluscs to the shells of which they can attach their tube-feet, while they can obtain no hold on the slimy surface of a Mollusc which has covered its shell by part of its soft tissues. Although the enemies to be guarded against are not the same in the Polyzoa, there may none the less be an advantage in having the calcareous parts covered with an organic membrane. The species which are especially liable to the attacks of *Folliculina* appear to be those in which the calcareous parts are but little protected, as in Cyclostomes such as *Lichenopora*; while this Infusorian readily establishes itself on dead parts of Cheilostomes which have lost the epitheca that covers their active regions. The encrusting species of Polyzoa doubtless prefer a hard calcareous surface on which to grow to a soft yielding membranous surface.

As a further factor with which the absence of avicularia may be correlated may be mentioned the shape of the individual zoœcia. There are many cases, such as *Schizoporella Cecilii, Mucronella ventricosa,* and a number of others, in which the zoœcia of a species devoid of avicularia are very convex in their external shape. The conjunction of a succession of convex zoœcia is probably important in preventing the encroachments of encrusting species, which more easily adapt themselves to a level surface than to one which is strikingly uneven or irregular. This is analogous to the case of *Flustra foliacea,* which we have already noticed, where the protection appears to depend largely on the development of spines. The irregular surface of many Cyclostomes, which is due to the projection of the free ends of the zoœcia, is probably similarly effective in preventing overgrowth by foreign organisms.

In the vibraculum the part that corresponds with the mandible of the avicularium has been prolonged into a thread-like structure, the 'seta,' which is moved by muscles corresponding with those of the avicularium.

The setæ of *Caberea* are very large, and they close into oblique grooves which run along the back of the branch. The protective value of these setæ is well shown in a specimen I have observed from Torres Straits, in which a minute encrusting Cheilostome has formed a single row of zoœcia along the region between two of the vibracular grooves, but has not extended into any part where it would be subject to injury by the movements of the setæ.

The vibracula are, however, probably used for other purposes besides the protection against living foes. They no doubt serve to brush away foreign particles which might otherwise settle on the surface of the colony and block up the orifices. This function has been suggested for the vibracula of the so-called Selenariidæ, a group of forms which agree in having a zoarium of a discoidal or inverted saucer-like shape. The colony is believed to rest freely on the bottom, on the edge of its concave base, though I have some evidence that it may be attached to the ooze by means of very delicate, flexible, rooting processes. Some at least of these Selenariiform species occur in situations where the ground is covered by *Globigerina*-ooze, the settlement of which on the convex surface bearing the orifices is probably prevented by the vibracula. It is now generally admitted that this type of colony has been independently acquired in several cases, the so-called family being in fact an entirely unnatural assemblage of genera. It may be worth while to point out in passing that I have noticed in several cases that the Selenariiform colony commences its existence on a Foraminiferan shell or other minute object, in the absence of larger surfaces on which fixation can be effected, and that the characteristic discoidal form is due to the growth of the circular edge of the colony beyond this initial supporting base.

But my object in introducing this group of Cheilostomes at the present point is to call attention to the relatively enormous size which is reached by the setæ of the vibracula of some of the species, a size which is so great that it has even been supposed that these appendages are used as oar-like organs of locomotion. In a specimen of *Selenaria hexagonalis,* from South Australia, in the Museum of Zoology at Cambridge, the setæ have been colonised by a minute Cheilostome belonging to the genus *Eucratea.* It might be said that in this case the setæ have almost overreached themselves, since they have become so large and powerful that another species is minute enough to find a home on the protective mechanism itself.

Having thus dealt with the probable functions of the avicularia and vibracula, we may now return to the consideration of the forms assumed by these appendages and of their distribution in the colony. The protective function which they appear to possess prepares us for finding, as is actually the case, that they are modified in an extraordinary number of directions. But although they occur, in one form or another, in the majority of Cheilostomes, they may be completely absent in an entire genus, in certain species of a genus, in certain varieties of a species, or in individual colonies of species which normally possess them. They are often wanting on some of the zoœcia, though present on most of the zoœcia, of a colony; and they may vary to a considerable extent in the position they assume on the zoœcium. Not only are they thus variable in their occurrence, but they show equally striking differences in their individual characters. They may be all of one kind in a single species, or two or more kinds may occur distinguished by size, by the shape of the rostrum and mandible, or in other ways. We thus come to the consideration of the question how far these appendages can be used in the discrimination of species.

The characters on which species are founded in a group of colonial animals like the Polyzoa obviously differ in certain respects from those which are used in distinguishing species in organisms that lead a solitary existence. In the colonial forms we are concerned partly with the mode of association of the individual units, partly with the manifestations of dimorphism or polymorphism shown by those units and partly by the features of the individuals themselves. Among the Cheilostomatous Polyzoa the dimorphism or even polymorphism of the individual, due to the presence in the colony of avicularia and vibracula, is of special importance.

While the characters of the avicularia have accordingly long been used by systematists for distinguishing species, no one—so far as I am aware—has hitherto suggested any hypothesis which helps us to form a reasonable conception of the significance of the innumerable modifications undergone by these organs; nor do I think that the problem has ever been fairly stated.

The difficulty of understanding the evolutionary significance of the avicularia arises in part from the fact that the occurrence and distribution of these structures appear in many cases to give but slight indications of affinities. It cannot, for instance, be assumed, without further evidence, that two species possessing an identical type of avicularium are nearly related. The complete absence of avicularia in a particular species is no sufficient reason for removing that species from an assemblage of forms in which avicularia are always present. And, lastly, there may be good grounds for believing that two forms with entirely different types of avicularia are closely related, and in some cases may even belong to the same species.

The result of a comparative study of the Cheilostomata leads in fact to the conclusion that although certain genera or species are characterised by the possession of one or more definite types of avicularium or vibraculum, other genera or species show no such constancy in this respect. The occurrence of the same type of avicularian appendage in the species of widely separated genera and the diversity of type of avicularium within the limits of a single genus or species render it most difficult to frame any theory that will account for the facts. Are we to assume that a given type of avicularium has been evolved independently in a number of cases, or must we suppose that species with that type have inherited it from a common ancestor? If the latter hypothesis be the correct one, we seem to be led to the conclusion that the ancestral Cheilostomes were provided with most of the types of avicularia that actually occur in existing species, many of which have lost one or more of those types.

In trying to arrive at some conclusion with regard to these points we may notice in the first instance one fact which stands out with great distinctness—namely, that, whatever the modifications of the avicularium may be, the mandible is usually either acutely pointed at its free end or rounded and spatulate at its termination. The difference may at first sight appear unimportant, but I am inclined to believe that it is an indication which may lead us to results of great significance.

Though it may be going too far to assert that all avicularia belong to one of these two types, there is usually no difficulty in recognising either the pointed or the rounded character in every avicularium present on a colony. The distinction may be observed by inspecting the form of the rostrum in a dry preparation of a part of the zoarium, but it is seen with more certainty when the mandibles have been isolated and are examined in Canada balsam. So striking is the difference that the inquiry naturally suggests itself whether there is any indication of the evolutionary meaning of the two kinds of avicularium. It appears to me probable that a condition which is characteristic of the existing genus *Steganoporella* may furnish the answer to this question. In this genus avicularia are typically absent, but in each species the zooecia are of two kinds, distinguished by differences in the shape and structure of the opercula and orifices. The anatomy of the zooecia is known in but few cases, but in those that have been observed both kinds of zooecia possess polypides. In one division of *Steganoporella* the more differentiated zooecia show some resemblances to the pointed type of avicularium, while in a second division they more nearly resemble rounded avicularia. I am inclined to believe that these conditions correspond respectively with the two kinds of differentiated avicularia of other Cheilostomes.

The avicularia most commonly met with occur as appendages of the ordinary zooecia, which alone constitute the main framework of the colony. But in addition to these, the 'adventitious' avicularia of Busk, we find, although less commonly, another kind known as the 'vicarious' avicularium, from the fact that it occupies the place of an ordinary zooecium, with which it agrees more or less closely in point of size. Its mandible is usually of the rounded type, appropriately referred to as 'duckbill-like,' and is readily seen to represent the operculum of an ordinary zooecium. Compared with this the mandible and the orifice which it closes are greatly enlarged, while the occlusor muscles have become correspondingly increased in size. The polypide is generally absent in the vicarious avicularium.

Pointed avicularia of the vicarious type occur normally in the species of

Onychocella, which, alike by their structure and by their early palæontological appearance, may be regarded as representing a primitive type of the Cheilostomata. Vicarious avicularia with a rounded mandible occur in certain species which I refer provisionally to *Siphonoporella*, as well as in a small proportion of the species of *Membranipora* and *Flustra*. All these may fairly be regarded as belonging to a comparatively undifferentiated type of Cheilostomata, and their vicarious avicularia are usually the only ones present. It is thus not improbable that the avicularium in these cases really represents an early stage of evolution. But we must notice that precisely similar rounded vicarious avicularia make their appearance occasionally in species of a much more differentiated type, as in the well-known *Schizoporella Cecilii* [1] and in certain other species which may for the present be referred to the same genus. In the majority of the very numerous species of *Schizoporella* vicarious avicularia are not known to occur, and it is thus impossible to regard them as a typical attribute of the genus.

The vicarious avicularia, which by their position and general structure are so easily comparable with the ordinary zoœcia, are usually supposed to represent an initial stage in the evolution of the avicularium. But if this view be correct, how are we to account for the sporadic way in which these structures occur in a series of genera such as *Membranipora*, *Flustra*, *Schizoporella*, and *Cellepora*, the last two of which at any rate are highly specialised in other respects? What conclusion can we draw from the association, in one and the same colony, of this type of avicularium with adventitious avicularia of the most specialised description? How can we explain the fact that each kind of avicularium occurs in certain species, but not in all the species, of many distinct and not specially related genera? And, lastly, what is the significance of the fact that certain species of a genus which is normally provided with avicularia may be totally destitute of these organs? These are some of the problems of which no satisfactory solution has at present been given. On the ordinary view of the way in which the species of a genus are interrelated we should perhaps not expect to find that two species which are closely similar in other respects may be distinguished by possessing entirely different types of avicularia.

I am aware of the fact that it is perhaps premature to indulge in speculations which are unsupported by experimental evidence. But it appears to me worth while to suggest that some of our difficulties might be removed by appealing to the results obtained by workers on Mendelian inheritance. An essential part of the theory here involved is that in the formation of the gametes of an organism there is a segregation of certain paired or 'allelomorphic' characters whereby some of the gametes are endowed with qualities by virtue of which they transmit one of the characters, while the rest of the gametes become capable of transmitting the characters of the other member of the allelomorphic pair. It has recently been made probable by Professor Bateson, whose views have been confirmed by others, that the actual appearance of a particular character may be dependent on a coupling of two allelomorphs belonging to distinct pairs. If only one of them is present the character will not show itself. The phenomenon of reversion on crossing is thus explained as due to the combination of allelomorphs present in the isolated condition in two parental forms.

Is it not possible that the perplexing occurrence of vicarious avicularia in some of, but not by any means in all, the colonies of certain species may be interpreted as a reversion due to the combination of two or more allelomorphs that may not have occurred together in the parental forms? We have seen that there is some reason to believe that these avicularia are really of an archaic character, from their occurrence in certain genera of a primitive type, known in some cases by palæontological evidence to have appeared early in the evolution of the Cheilostomata. We may further remember that we have distinct evidence that Cheilostomes of a differentiated type may retain certain primitive characters, in the occurrence of a *Membranipora*-like form of ancestrula in so many of them. If, then, we may suppose that the appearance of vicarious

[1] Kirkpatrick, *Ann. Mag. Nat. Hist.* (6), v. 1890, p. 21.

avicularia is due to a combination of more than one allelomorph we may recognise the possibility that the ancestrulæ of a given species still carry the determinants representing those allelomorphs. In species in which the vicarious avicularia are of normal occurrence there is no difficulty in this hypothesis. In others, of which examples may be found in *Schizoporella,* the vicarious avicularia make their appearance rarely, in a very small proportion of colonies. In these cases the facts might be accounted for on the hypothesis of the chance recombination of allelomorphs which are ordinarily separated, unless indeed it should prove to be the case that the vicarious avicularia represent a recessive character which is usually prevented from making its appearance by some dominant factor.

A single series of cases of this kind will not carry conviction, but there are many facts with regard to the distribution of adventitious avicularia that may point in the same direction. We may recur to the fact that the form of these appendages may be eminently characteristic of a whole series of species which from their similarity in other respects are naturally associated in a single genus or family. The most striking instance of this is, perhaps, the genus *Bugula,* in which we find the avicularium *par excellence.* The variations of this type of avicularium are comparatively slight and for the most part depend on differences in position with regard to the zoœcia and on minor modifications of size, shape, and length of stalk. Both in *Bugula* and in the allied genus *Bicellaria* the avicularian characters may be described as relatively constant; and since they belong to a type that is rarely met with in other genera, they seem to confirm the evidence afforded by other structural features that the species which possess them are related to one another. But even in *Bugula,* where the avicularia reach the summit of their development, we meet with species or varieties in which these appendages are invariably absent throughout the colony. This may be illustrated by *Bugula neritina,* a widely distributed species which in the Mediterranean and certain other districts is remarkable for the complete absence of avicularia, although in other structural features it shows a close affinity to other species of *Bugula.* In Australian and Oriental waters, however, there occur forms which can hardly be distinguished from *B. neritina* except by the fact that they always possess numerous avicularia of the specialised character that is so distinctive of the genus. It does not matter for our present purpose whether these are to be regarded as a variety of *B. neritina* or not. If the appearance of avicularia may be regarded, on Mendelian principles, as due to the presence of one or more allelomorphs, it is possible to understand that these may be omitted in certain cases, and that there may thus be a close affinity between two forms one of which differs from the other in what appears at first sight so essential a respect as the complete absence of the avicularia which we are justified in regarding as the most important feature of the genus.

A second case of the same general nature may also be noticed. In the family Cellulariidæ are included a number of delicate erect species which are commonly placed in the genera *Caberea, Scrupocellaria, Menipea,* and *Cellularia.* The first two of these are distinguished by possessing vibracula as well as avicularia. *Menipea* is defined as possessing avicularia, but no vibracula; while *Cellularia peachii* does not possess either kind of appendage. A species known as *Amastigia nuda* has been placed in a separate genus because of the absence of vibracula and their replacement by avicularia, while in other respects it agrees with *Caberea,* in which the vibracula reach a development not exceeded by those of any other Cheilostome. Before considering the bearing of these facts we may appropriately consider another instance taken from the same family, although by doing so we are for the moment leaving the question of the avicularia. In the genera *Caberea, Scrupocellaria,* and *Menipea* certain species are distinguished by having the free surface of the zoœcium protected by a peculiar spine known as the 'scutum,' which is usually flattened and much expanded at its free end, where it overarches the membranous frontal surface in such a way as to cover and presumably to protect it. But in each genus other species are characterised by the complete absence of the scutum, while in others it occurs in varying degrees of reduction.

We have thus several cases in which certain species differ from their near allies in the complete absence of a structure which is, as a rule, one of the most distinctive features of the genera to which they are respectively assigned. Should it be possible to prove that the appearance of the organ in question, whether avicularium, vibraculum, or scutum,[1] was of the nature of an allelomorphic character, its disappearance would be readily intelligible.

The facts which I have indicated with regard to the so-called Cellulariidæ have not hitherto been sufficiently discussed; but I imagine that most systematists who have considered the question have assumed that the scutum, for instance, has undergone parallel evolution in *Caberea*, *Scrupocellaria*, and *Menipea*, either having been independently evolved in each of the three cases (a most improbable supposition), or having independently undergone a series of regressive changes of precisely similar character in the three genera.

But it is perhaps in the mode of occurrence of adventitious avicularia that we find the strongest reason for believing in the existence of some form of alternative inheritance. We may indeed go as far as to assert that alternative development does actually take place, whether the explanation of the facts is given by the Mendelian theory or not. The difference between the pointed and the round avicularia is a very definite one, which—it is no exaggeration to say—may be observed in hundreds of species. When these species are arranged under genera according to the result of a study of the whole of the evidence derived from all the characters that have proved valuable in classification, we find that many genera include some species with one type of avicularium and others with the other type. It should perhaps be pointed out that the validity of many of these genera is a matter on which differences of opinion exist. The subject is undoubtedly a difficult one, and we are far from having arrived at any certainty with regard to the classification of the Cheilostomata. But it is perfectly certain that we could not utilise the two kinds of avicularia in dividing these Polyzoa into two main series, since there are innumerable cases in which both kinds occur in a single colony. This is a fact to which I shall return later.

We may accordingly maintain that, although much is probably faulty in our present system, we have clear evidence that the same genus may include species which differ in the type of avicularium; and, moreover, that these are not exceptional, but, on the contrary, are of common occurrence. A few instances will make these points clear.

In the encrusting species and in certain others the avicularia commonly occur, as we have already seen, in a position near the orifice of the zoœcium, where they are usually either lateral or suboral. In one of the species with lateral avicularia these appendages may be of the pointed type, while in another they may be rounded; and the same statement may be made with regard to the suboral avicularia. Within the limits of the same genus we may further notice that certain species have lateral avicularia, while others have suboral avicularia. Here, again, we find the same indifference as to the shape of the rostrum and mandible.

If we might provisionally suppose that the two kinds of avicularia constituted an allelomorphic pair, represented by Aa, and that the lateral and suboral positions indicated a second allelomorphic pair, Bb, the four combinations, AB, Ab, aB, ab, would be theoretically possible. We might, in other words, have pointed or rounded lateral avicularia, and pointed or rounded suboral avicularia. All these conditions actually occur in such genera as *Lepralia* and *Schizoporella*; and, in some cases two species which agree in the form of the avicularia but differ in their position, or agree in the position but differ in their form, appear on other grounds to be nearly related, one to the other.

Other cases may be taken from *Retepora*, an instance where we may feel ourselves on comparatively secure ground, since there are strong reasons for believing

[1] The case of the scutum is less striking than that of the other structures under consideration, since conditions intermediate between full development and complete absence are not uncommon.

the genus to be a natural one. The genus as a whole possesses an almost bewildering variety in the form, position, and size of the avicularia, among which, however, we may distinguish the following kinds: (i) The suboral avicularium, closely related to the orifice and usually termed 'labial,' because it occurs on what may be described as the lower lip; (ii) frontal avicularia, on some part of that surface of the zooecium which bears the orifice; (iii) basal or dorsal avicularia, on the backs of the branches; (iv) fenestral avicularia, which guard the edges of the fenestræ or meshes of the colony.

In many of the species of this large genus the suboral avicularia are of the small rounded type. In other species they are small and pointed, with an acute mandible; while others are distinguished by possessing suboral avicularia that may be described as gigantic.

Among the frontal avicularia similar differences exist. In one case that has come under my observation a remarkable variation of this kind is found within the limits of a single species. Remembering the great difficulty there often is in arriving at certainty with regard to the limits of the species in the genus under consideration, I wish to emphasise the fact that this instance is taken from *Retepora phœnicea*, a form that not only has well-marked specific characters of the ordinary kind, but is remarkable in having a beautiful carmine-red or violet colour, a respect in which it differs from most of its nearest allies. The frontal avicularia of this species are usually of the pointed type, but in the variety in question—a colony from Torres Straits—they are, so far as I have been able to ascertain,[1] all of the rounded kind.

The fenestral avicularia show a similar behaviour. In South Australian waters there are a number of forms which are regarded as varieties of *Retepora monilifera*. In the form known as var. *munita* there is usually a suprafenestral avicularium of large size, distinguished by having a rounded mandible, which is a good deal broader than it is long.[2] In another form of the same species, distinguished by MacGillivray as var. *acutirostris*, the *munita*-avicularium may either occur as such in some of the fenestræ, or be replaced in others by a large avicularium of the typical pointed form.

In other species a gigantic infrafenestral avicularium commonly occurs, but while these structures are found in a considerable proportion of the fenestræ of some colonies they appear to be completely absent in other colonies. In this series of cases, which is well illustrated by *Retepora phœnicea*, I think there is clear evidence that different colonies, from the same locality and belonging to the same species, may show the two conditions of presence and absence respectively of fenestral avicularia. According to the ordinary criteria by which species of Polyzoa are discriminated, it might be necessary to place these in different species—a result which is not supported by other evidence. I think we must conclude that a species may have the faculty of entirely dropping out some complete series of organs, like certain kinds of avicularia. The Mendelian principle may here come to our aid by showing the theoretical possibility of having the two conditions represented in a series of colonies of identical parentage. If this should really be the explanation of the facts, it should occasion no surprise if some members of the immediate progeny of a colony in which a certain type of avicularium is absent should be found to be provided with a complete armature of these appendages.

The cases so far considered may conceivably be explained on ordinary Mendelian lines by assuming that an entire colony is homozygous or heterozygous with regard to particular characters. Remembering that the so-called ancestrula,

[1] It may be noted that it is extremely difficult and often impossible to make a study of every part of a large and irregular Retepore sufficiently exhaustive to justify one in asserting positively that all parts are identical in respect of their avicularia.

[2] This characteristic *munita*-avicularium is probably merely an enlarged form of the small circular type of avicularium met with as labial avicularia and in other positions in many species.

or primary individual, does not show all the characteristics of the mature colony, we must, however, assume that the determinants present in it do not find their full expression until the budding process has commenced.

But we are by no means at the end of our difficulties, even in considering the distribution of the appendages we have so far discussed. The instances already given have for the most part been cases in which an entire colony differs in certain respects from other colonies. We have still to notice the common case in which there are differences in different parts of one and the same colony. No theory can be considered complete unless it is able to account for these differences.

I approach this part of the subject with great trepidation, conscious as I am of the absence of experimental evidence for the suggestion I wish to make This suggestion is, briefly, that if a segregation of characters normally takes place in the formation of the gametes of an organism, it is conceivable that an analogous segregation may occur in the blastogenic processes, or, in other words, in the formation of a bud. It may be asserted positively that there is a very definite differentiation of individuals at this time, not only in the Polyzoa, but also in other animals which increase by budding. The fact that some of these differentiations appear to be alternative suggests the possibility that they are due to a process which resembles the Mendelian segregation of determinants in the gametes.

One of the instances which appears to me specially suggestive in this connection is the genus *Steganoporella*, the species of which are remarkable for the dimorphism of their zoœcia. This dimorphism is expressed, as we have already seen, by differences in the opercula and in their muscles, and in the form of the orifices which are closed by the opercula. It is not too much to say that every individual in a *Steganoporella* colony belongs to one of the two types in question; and, so far as I am aware, intermediate forms of zoœcium do not occur. It is thus a positive fact that the blastogenic tissues undergo some sort of differentiation of an alternative character, and there is at present no reason for believing that the differentiation is in any way correlated with the production of sexual cells by either of the two kinds of zoœcia.

Another case which seems to me specially suggestive is that of the simultaneous occurrence in the same colony of two different kinds of avicularia. These instances are not confined to a few species, but may be found in a number of genera which do not constitute a single assemblage of related forms. The pointed and rounded adventitious avicularia may be scattered about promiscuously in the same colony, or even on the same zoœcium. Sometimes avicularia of one of the two types normally occur in a particular position, but are occasionally replaced by avicularia of the other kind, an example of a general phenomenon to which Professor Bateson has given the name of 'homœosis.'

Excellent illustrations of this substitution may be taken from the genus *Retepora*. In the *R. monilifera* series already considered the *munita* and *acutirostris* types of avicularia may occur in different fenestræ of the same colony. *R. granulata* usually possesses a labial avicularium and a frontal avicularium, both of the small rounded kind. In one of the colonies of this species dredged by the 'Siboga' most of the labial avicularia are of this type, but a certain proportion of the zoœcia have a pointed labial avicularium. In another colony most of the *frontal* avicularia are small and round, but in some of the zoœcia they are large and pointed. In both instances the examination of the mandibles proved the reality of the distinction inferred from the shape of the calcareous parts.

Instances of a similar substitution could easily be multiplied, while the cases of the simultaneous occurrence of the two kinds of adventitious avicularia are innumerable. Without going so far as to say that intermediate conditions do not occur—a generalisation that could only be established by very prolonged study—it may certainly be maintained that it is the general rule for an avicularium to assume one of the two types. In a suitable preparation it is usually quite easy to sort all the mandibles into their proper group at first sight, and without having to pause to consider doubtful cases. This fact is surely significant, and it can at least be argued that in the blastogenic processes by which the avicularia have been developed some differentiation or segregation must occur by which the two kinds are constituted. If this differentiation should prove to be analogous to the segregation which occurs during the formation of gametes we should be able to account for much that is at present perplexing in the polymorphism of the Cheilostomata. We should in particular not be precluded from regarding a colony with avicularia of one type as nearly related to other colonies which possess avicularia of the other type; and we should have some explanation of the fact that many of the genera possess all the different forms of avicularia which are variously distributed among their constituent species.

I have so far spoken as if the adventitious avicularia belonged to two types only. This statement requires some further qualification, although it may nevertheless be true that all the forms can be referred to one or other of the two principal kinds. As a matter of fact a single Cheilostome colony may bear more than two sorts of avicularia; as, for instance, appendages with large pointed mandibles, in addition to two kinds of those with small rounded mandibles.[1] This introduces a further complication, about which it is unnecessary to speculate at present.

It may naturally be asked whether there are any numerical facts which support the suggestions I have made with regard to the significance of the different forms of avicularian appendages. I must admit that the numerical relations are so complicated and apparently so variable that I have not been able to draw any definite conclusion from them.

Experimental evidence is at present wanting, nor would it be easy to devise crucial tests. Even if it were possible to experiment with two colonies of the same species which differ in their avicularian appendages, the result might be negative, since it is not possible to say definitely whether the eggs of a given colony are normally fertilised by the spermatozoa of the same colony or by those of a different colony. Some light may conceivably be obtained from observations on the regenerative processes which may occur in Polyzoa. A recent paper by Levinsen [2] gives some information with regard to this point, and there are a few other observations on the same subject scattered through the literature of the Polyzoa.

It is thus obvious that the speculations in which I have permitted myself to indulge cannot be regarded as more than a guess as to the significance of the causes which underlie the facts observed; but, whether the view I have outlined has anything to recommend it or not, the observations on which I have depended are, I think, correct. If this be the case, some explanation of the facts is urgently required. The decision of the principles on which the Polyzoa should be classified may not be a matter of immediate practical importance, but our theories of species cannot be regarded as established until they have shown themselves capable of explaining all the cases. Some modification of the Mendelian theory seems to me to be capable of elucidating the apparently haphazard way in which the several forms of avicularia are distributed in the species of Cheilostomata, and it may perhaps be allowed to afford a working hypothesis that can be used in systematic study. The results of such a hypothesis would, I think, be far-reaching. Whether we are justified in accepting it provisionally or not, I am convinced that we require some hypothesis by which we may regard two specimens as belonging to the same species, even though they may differ in what might at first sight seem

[1] In the species of *Retepora*, for instance, there may occur the following types of avicularia, in addition to others that need not be mentioned: Conspicuously large avicularia, some of which are usually fenestral, either pointed (*a*) or rounded (*b*); small avicularia, either pointed (*c*) or rounded, these latter occurring as two well-marked types in which the mandible is respectively longer than broad (*d*) or broader than long (*e*). The following combinations may occur in individual species or colonies: $a+c+d$, $a+d+e$, a alone, $b+c$, $b+d$, and others. Examples of some of these combinations may be seen in Busk's Report on the Polyzoa collected by H.M.S. *Challenger* (Part XXX., 1884).

[2] 'Sur la Régénération totale des Bryozoaires,' *Acad. Roy. des Sci. de Danemark, Bull. de l'année* 1907, N° 4.

to be fundamental respects. And, *vice versa,* we require the liberty to regard two species as widely separated from each other in the system, even though they possess identical types of avicularia.

There are other questions which might have been considered in the Cheilostomata, and, in particular, the presence or absence of oral or marginal spines and the forms and distribution of the ovicells. The occurrence of the latter is, however, probably connected with the presence in the young zoœcium of tissue which will give rise to an ovary; and this implies the consideration of another factor which is very difficult to estimate.

I must not conclude without at any rate referring to the fact that the Polyzoa are by no means the only animals in which dimorphism or polymorphism occurs as the result of blastogenic processes. But among the Cœlenterates, for instance, the occurrence of medusoid individuals cannot be considered apart from the question of the sexual cells. There is, however, one series of cases among Hydroids to which allusion may perhaps be made. I refer to the existence of pairs of genera such as *Corymorpha* and *Tubularia, Syncoryne* and *Coryne, Podocoryne* and *Hydractinia,* in each of which pairs the two genera are distinguished by the fact that one produces free medusæ, while the other has sessile gonophores. There is already some evidence that the validity of these generic distinctions is open to question; and the free medusoid individual and the sessile gonophore might conceivably be related in such a way as to form members of an allelomorphic pair. The same phylum contains another striking example of dimorphism in the distinction between gastrozooids and dactylozooids in many Hydroids; while in the Siphonophora the differentiation of various forms of individual has advanced much further.

But I have already gone much beyond my evidence, and I must bring my remarks to a conclusion by expressing the view that the causes which regulate the differentiation of the individuals during the blastogenic development of the Polyzoa are well worthy of further study, and that our knowledge of the unity of the vital processes throughout the animal kingdom gives us reason to believe that they are part of some general Biological law.

The following Papers were then read:—

1. *The Migratory Movements of certain Shore-Birds as observed on the Dublin Coast. By* C. J. PATTEN, *Sc.D.*

While the majority of my observations, extending over twenty years, on the migratory movements of shore-birds along the Dublin coast have been incorporated in my work entitled 'The Aquatic Birds of Great Britain and Ireland,' published at the end of the year 1906, I still continue to visit my former hunting-grounds, and, with the aid of trustworthy correspondents, have collected further information on the subject. To add to my personal observations and to enable me to bring before this meeting of the British Association information as recent as possible, I selected the Dublin coast this autumn as a seaside resort. I would refer particularly to the Sanderling (*Calidris arenaria*). There is now strong evidence to show that this bird is found in adult plumage throughout the breeding-season on that coast. The observations of Mr. A. Williams, made in July 1906 in this locality, on the Sanderling are of interest, as there was an unusually large gathering of adult birds recorded. In many ways the Turnstone repeats the migratory movements of the Sanderling, and is found throughout the year on the Dublin coast in adult plumage. I have, moreover, dissected the genitals of the female bird, shot at the height of the breeding-season, and have found quite ripe ova. The time will, I believe, yet come when this species will be discovered breeding on the Irish seaboard, or perhaps along the shores of inland lakes. The movements of the Little Stint are most irregular; a few pairs appear during some autumn seasons, but in 1902 I have records of flocks from the locality in question. The tameness of certain shore-birds on their first arrival on the coast is remarkable, such species often only remaining a few days. This is particularly interesting to those of us wishing to avail ourselves of the short opportunities we have of watching them.

The paper was illustrated by a series of lantern-slides, and of skins of specimens collected by the author, illustrating curious phases of plumage-changes, according to sex, age, and season.

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2. *A Biological Expedition to the Birket el Qurun, Fayum Province of Egypt. By* W. A. Cunnington, *B.A., Ph.D., and* C. L. Boulenger, *B.A.*

The lake known as the Birket el Qurun has a unique interest, since it is the remains of the historic Lake Mœris, which was used as an artificial regulator of the Nile floods by the monarchs of the twelfth dynasty. Our expedition was undertaken in the spring of last year at the instigation of Captain Lyons, F.R.S., the Director-General of the Egyptian Survey Department.

While the Birket el Qurun is still of considerable size, being about twenty-five miles long and having a maximum breadth of five or six miles, it is very evident to the present-day observer that a remarkable reduction in size has taken place. Raised beaches may be clearly recognised in many parts, and the lake is extremely shallow, the greatest depth being between four and five fathoms. The water, too, is sufficiently brackish to be quite unpalatable, and its density is above that of fresh water. It is thought that the surface of the lake was formerly as much as 70 feet above sea-level; now it is some 140 feet below the level of the Mediterranean.

The lake was found to be well stocked with forms of life, but apparently the number of species is not large. With the tow-net there were taken large quantities of Entomostraca—principally copepods and cladocera—as well as great numbers of rotifers. Very little phyto-plankton was obtained.

The Entomostraca doubtless form the food-supply of the fishes, which occur in astonishing abundance. Fifteen species of fish were obtained, belonging to seven families. All are well-known Nile forms, but more than half were secured for the first time by this expedition. A large specimen of the so-called Nile perch (*Lates niloticus*) was examined, which measured 120 cm. and weighed 54 pounds.

The swampy pools on the margin of the lake yielded ostracods, hydrachnids of the genus *Eulais*, and five species of spiders. The mollusca belong to eleven species, all of them being Nilotic forms. Among these mollusca only two species of lamellibranchs are included. A small oligochæte—*Paranais littoralis*—is the only aquatic worm obtained, as leeches and turbellaria appear to be absent.

Our collection contained also a gymnolæmatous polyzoan, with a circular ophophore and eight tentacles. *Cordylophora* was found growing in great abundance in the lake. Its occurrence is of considerable interest, since it has not previously been recorded from Africa, and is not known to occur in the Nile, with which the Birket el Qurun is in direct communication. The most interesting discovery was that of a medusa and the associated hydroid stage. This form, which has been named *Mœrisia Lyonsi*, appears to bear a resemblance to the marine genus *Sarsia*. Whatever its exact affinities, it is difficult to account for its presence in the Birket el Qurun.

The algæ and the truly aquatic higher plants were also collected. Among the latter, specimens of *Potamogeton interruptus* and *Chara vulgaris* are of interest, since they show slight differences from the common forms.

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3. *On the Distribution of Irish Freshwater Mites* (Hydrarachnida). *By* J. N. Halbert.

The author described the various stages in the life-history, and the importance of the parasitic larval stage in the dispersal of the various species over large areas. The geographical distribution of the species is very imperfectly known, but the majority are more or less widely distributed, and may be placed in at least two great faunistic groups. One group inhabits the lowland waters of a comparatively high temperature, while the other is especially characteristic of highland lakes and streams possessing a deeper temperature. Both groups show many interesting structural modifications in harmony with their natural environment.

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4. *On some Arctic and Antarctic Collembola.* *By* Professor George H. Carpenter, *B.Sc., M.R.I.A.*

The last ten years have been marked by great advances in the systematic study of the Collembola or springtails. Collections from many parts of the world have been worked out, but the most striking results have been obtained from the examination of specimens brought from the Arctic and Antarctic regions by various expeditions. The comparative richness of the Collembolan fauna of remote northern and southern lands is remarkable. In the Arctic, Greenland has about 20 species of springtails, Spitzbergen 16, and Franz-Joseph Land 7; while in the Antarctic, Kerguelen has 5, Graham Land and the South Shetlands 4, South Georgia 6, the Falklands 10, and South Victoria Land at least 2.

According to the views of most recent students, the Poduridæ and the Isotominæ are nearest to the primitive stock of the order, the Entomobryinæ, the Tomocerinæ, and the Symphypleona being more highly specialised. It is suggestive to find that in both the Arctic and Antarctic faunas the primitive sections are well represented, while the specialised genera have but very few species. And in the more remote and insular regions the higher groups seem entirely absent.

Of much interest is the presence of two Arctic Isotomines in our own islands. These are *Agrenia bidenticulata* (Tullb.), a species both Arctic and Alpine, discovered last year in Irish and North British mountain streams, and *Proisotoma Beselsii* (Packard), which inhabits the Arctic regions of both the Old and New Worlds and the coast of Scotland. 'Bi-polarity' in the Collembola is shown by Wahlgren's recent record of this latter species from Terra del Fuego and by the presence of a closely allied form (*Proisotoma Brucei*, Carp.) on the South Orkneys. Such distribution indicates a high antiquity (probably Mesozoic) for the species.

A similar conclusion is suggested by a comparison of the distinctively Antarctic springtails. Several genera are apparently confined to the southern regions. Among these Cryptopygus (Willem) is represented by identical or nearly allied species in Terra del Fuego, Graham Land, South Shetland, South Orkneys, and South Georgia. Turning to genera of wider range we find the same Isotoma (*I. octo-oculata*, Willem) present in Graham Land, South Shetland, South Orkneys, and Kerguelen, while the Isotoma of South Victoria Land (*I. klovstadi*, Carp.) is closely allied to a Fuegian species. Such distributional facts suggest a considerable geological age for the species and a former wide extension of the Antarctic continent.

The National Antarctic ('Discovery') Expedition collected from moss at Granite Harbour, South Victoria Land, a remarkable springtail, referable to the Poduridæ, but showing some striking affinities to the Isotominæ. This insect—apparently the most southerly terrestrial animal yet known—will be described and figured in the forthcoming part of the Expedition Reports.

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5. *On Diaposematism, or the Interchange of Characters between Distasteful Forms.* *By* F. A. Dixey, *M.A., M.D.*

When in the year 1879 Fritz Müller put forward his theory of common warning colours, or the assimilation of one distasteful form to another for the sake of mutual protection against insectivorous enemies, he recognised the probability, or even certainty, that the approach would not necessarily be one-sided, but might be in the strict sense convergent, each form in some respects advancing to meet the other. This suggestion, however, so far as F. Müller was concerned, remained only in the theoretical stage; it was never developed by him, and although he mentioned a few instances in support of his view, he did not attempt to trace the supposed mutually mimetic process in any detail. There is, nevertheless, much evidence that such reciprocal approach, or interchange of obvious characters, does actually occur; and some cases of mimicry are here exhibited, the peculiar features of which are difficult to explain on any other hypothesis.

Thus the resemblance between *Leuceronia pharis*, Boisd., and the form of *Nychitona medusa*, Cram., which inhabits the same districts of Central Africa, appears to be due to mutual assimilation, the *Leuceronia* having borrowed its peculiar outline and the attenuation of the dark apical patch from the *Nychitona*, while the wings of the latter form owe their spotlessness and the comparative opacity of their white pigment, in both of which respects they differ from the forms nearest to them by affinity, to imitation of the *Leuceronia*.

Similarly, the mimetic relation between *Heliconius* as represented by *H. guaricus*, Reak., or *H. haenschi*, St. and Riff., and certain Pierines or 'white' butterflies such as *Pereute leucodrosime*, Koll., and *Pieris locusta*, Feld, may very possibly be due to an interchange of certain features between them.

Again, there is in the Island of Bali a certain Pierine butterfly, *Ixias baliensis*, Fruhst., the female of which presents a general resemblance to another Pierine, *Huphina corva*, Wallace, found in the same island. In view of the usual aspect of the nearest allies of these two forms respectively, the conclusion suggests itself that the *Ixias* has assimilated its forewing to that of the *Huphina*, and the *Huphina* its hind wing to that of the *Ixias*.

The females of certain Central and South American Papilios, or 'Swallow-tails' (as *P. iphidamas*, Fabr., *P. nephalion*, Godt., &c.) are in close mimetic relation with both sexes of some common species of the Pierine genus *Euterpe* (e.g., *E. approximata*, Butl., *E. tereas*, Godt., &c.) The suggestion is offered that although in most respects the Papilio has plainly influenced the Pierine, it is yet due to the influence of the latter that the females of the former have not adopted more closely the aspect of their own males.

For this phenomenon of mutual approach, or reciprocal influence, the term Diaposematism has been proposed by Professor Poulton. The possibility of its occurrence has been questioned on *a priori* grounds, but, it would appear, without sufficient reason.

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6. (i) *Mimicry in the Butterflies of North America.* (ii) *Recent Investigations upon the African Swallow-tail Butterfly* Papilio dardanus (merope) *as an Example of Mimicry. By* Professor E. B. Poulton, *F.R.S.*

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7. *Some of the chief Mimetic Combinations among South American Butterflies. By* J. C. Moulton.

FRIDAY, SEPTEMBER 4.

The following Papers and Reports were read:—

1. *An Inquiry into the Feeding Habits of British Birds. By* C. Gordon Hewitt, *M.Sc.*

It is becoming increasingly difficult, with the introduction of scientific methods into agriculture, horticulture, and forestry, for zoologists studying economic problems to form a definite opinion with regard to the economic status of many species of the birds of our islands, such as, for example, the rook, jay, starling, chaffinch and other finches, and many other birds.

This difficulty is entirely due to the almost complete absence in this country of any precise information as to the food habits of our birds. There exists a large amount of evidence obtained from observers, such as fruit-growers, gamekeepers, sportsmen, and others; and although some of this may be and is useful, much of it has been distorted on its way, through the prejudiced glasses of the observer. What is really necessary in order to obtain as accurate a conception as possible of the economic status of any species of bird is the actual dissection and recording of the contents of the crops and stomachs of a large number of individuals killed, not only in different months of the year, but also in different localities, since different conditions exist in different regions, for example, in Kent and Lancashire.

Such evidence is the only real and safe guide, and observational evidence, after careful selection, must only be taken as supplementary.

Very little work of this nature has been accomplished in this country, but until it is done the regulations with regard to the protection of birds will be ever subject to the influence of the personal bias or ignorance of the legislators, and such legislation will be on as equally a sound foundation as many of the fisheries regulations were until the advent of scientific fishery investigations.

The Biological Survey Bureau of the United States Department of Agriculture furnishes an excellent example of the kind of work that should be carried out; it is collecting and publishing a valuable mass of information concerning the feeding habits of birds and their nestlings, from which, in the majority of cases, they are able to deduce the precise economic value of these birds. The Central Bureau for Ornithology of the Hungarian Department of Agriculture is doing similar work.

It is proposed to form a British Economic Ornithological Committee, as such work can be best carried out by a number of biologists working together. At the last annual meeting of the Association of Economic Biologists, held in April 1908, the author moved the following resolution, which was carried unanimously:—

'That this Association, recognising the great need of an organised inquiry into the feeding habits of the birds of the British Isles, with a view to obtaining a precise knowledge of their economic status, is of the opinion that a committee should be formed with the object of carrying on investigations on this subject.'

The Board of Agriculture, recognising the importance of the subject, have romised to help the inquiry.

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2. *On the Abuses resulting from the strict Application of the Rule of Priority in Zoological Nomenclature, and on the means of protecting well-established Names.* *By* G. A. Boulenger, *F.R.S.*

Disapproval was expressed of the extreme application of the rule of priority, which in the author's opinion had brought about much mischief under pretence of aiming at ultimate uniformity.

The author protested against the abuse to which this otherwise excellent rule had been put by some recent workers, encouraged as they were by the decision of several committees who had undertaken to revise the Stricklandian Code, elaborated under the auspices of the British Association in 1842.

The worst feature of this abuse is not so much the bestowal of unknown names on well-known creatures as the transfer of names from one to another, as we have seen in the case of *Astacus, Torpedo, Holothuria, Simia, Cynocephalus,* and many others which must be present to the mind of every systematist.

The names that were used uniformly by Cuvier, Johannes Müller, Owen, Agassiz, Darwin, Huxley, Gegenbaur, would no longer convey any meaning, very often they would be misunderstood; in fact, the very object for which Latin or latinised names were introduced would be defeated.

It is all very well to talk of uniformity in the future, but surely we must have some consideration for the past.

Names with which all general zoologists, anatomists, and physiologists are familiar should be respected, should be excepted from the rule in virtue of what may be termed the privilege of prescription, If biologists would agree to make that one exception to the law of priority in nomenclature, things would adjust themselves well enough, and we might hope to see realised some day what we all desire, fixity in names, that we may readily understand the meaning of all writers, not only over the whole civilised world, at the present day and in the future, but back into the last century, which has marked so great an advance in zoological science.

Such a result would be attained by protecting time-honoured names of well-known animals from the attacks of the revisers of nomenclature. For this purpose future committees that may be convened to discuss these topics might confer a real and lasting benefit on zoology by determining, group by group, which names are entitled to respect, not of course on the ground of their earliest date or their correct application in the past, but as having been universally used in a definite sense.

This suggestion is not a new one. As far back as 1896, in a discussion which took place at the Zoological Society of London, Sir E. Ray Lankester, protesting against the digging up of old names, suggested that an international committee should be formed, not to draw up a code of rules, but 'to produce an authoritative list of names—once and for all—about which no lawyer-like haggling should hereafter be permitted.'

Twelve years have elapsed, and nothing of the kind has been arranged. On the contrary, the various committees that have legislated since have insisted on absolute priority, and we often read that such a decision has been arrived at by international agreement. It is not so, a great body of zoologists in this country protest, and hope that something will be done towards carrying out the proposal here briefly set forth, which seems to be the only proper step to take in order to prevent the confusion with which we are menaced.

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3. *The Vascular System of* Stylodrilus. *By* Rowland Southern.

The genus *Stylodrilus* has hitherto been distinguished from other European genera belonging to the Oligochæte family Lumbriculidæ by the absence of the blind contractile appendages of the blood-vessels, which are so characteristic of the family. The new species investigated, but not yet described, from the river Annalee, co. Cavan, Ireland, undoubtedly belongs to the genus *Stylodrilus*, but differs from all the other species in the possession of simple contractile appendages to the dorsal vessel. These blind sacs are restricted to the posterior end of the worm and are simpler in structure than those of any other Lumbriculid. This species thus forms an interesting link between the normal Lumbriculid type and the aberrant genus *Stylodrilus*. The relations of the dorsal and ventral vessels to the intestinal blood-sinus are also investigated, and shown to differ considerably from the condition typical of the Oligochæta.

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4. *Giant Nerve Cells and Fibres.*[1] *By* Dr. J. H. Ashworth.

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5. *The Respiration of Land Isopods.* *By* Ernest Ewart Unwin.

The woodlice belong to an aquatic family, and it is interesting to see how they fare in their new environment.

Taking *Asellus aquaticus* as a typical aquatic isopod, *Ligia oceanica* perhaps comes nearest in habitat and general structure. The respiration is effected by the abdominal appendages, which are platelike. The outer plate (exopodite) is stouter than and covers the thinner inner plate (endopodite). If kept damp, oxygen is extracted from the air by these plates.

[1] Published in *Phil. Trans. R.S.*

Oniscus asellus, the common brown slater, resembles *Ligia* in the general structure of its respiratory organs. It has, however, a curious additional breathing-organ at the outer edge of each exopodite. This is scooped out beneath to form a very thin-walled air-chamber.

Porcellio scaber is noteworthy on account of the presence of whitish patches upon the first two pairs of abdominal exopodites. These are caused by minute air-tubes excavating the exopodite. It is interesting to find an independent acquisition of air-tubes, although they exhibit none of the perfections found in insects' tracheæ. The habitat of *Oniscus* is distinctly damper than that of *Porcellio.*

A large number of experiments were tried with these two kinds of woodlice under very wet and very dry conditions, the results being that *Oniscus* outlived *Porcellio* when submerged; but *Porcellio* easily outlived *Oniscus* under dry conditions.

Several other genera of woodlice were examined, their habitat noted, and a large number of similar experiments conducted, with the result that the common genera can be arranged in an ascending series from a wet to a drier habitat, and the structure of the respiratory organs shows corresponding modifications; in fact, the one is the result of the other.

These results can be tabulated thus:—

HABITAT.	ISOPOD.	RESPIRATORY ORGANS.
Aquatic	*Asellus aquaticus*	Gills.
High-water line	*Ligia oceanica*	Gills, with stouter exopodites.
Wet grass	*Trichoniscus pusillus*	Ditto.
Dampish places	*Oniscus asellus* *Philoscia muscarum*	Gills, with special air-chambers at edge of exopodites.
Drier places	*Porcellio scaber*	Air-tubes in two pairs of exopodites.
Dry places (often very dry)	*Armadillidium vulgare*	Ditto, with power of rolling up.

Cylisticus convexus has air-tubes in five pairs of exopodites, and can also roll up; but this has not at present been found in sufficient numbers to verify by experiment its place in the above list.

The author is undertaking further inquiries into the bionomics of this group.

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6. *Report on the Occupation of a Table at the Zoological Station, Naples.* See Reports, p. 297.

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7. *Report on the 'Index Animalium.'*—See Reports, p. 297.

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8. *Report on Experiments in Inheritance.*—See Reports, p. 298.

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9. *Report on the Fauna of the Lakes of Central Tasmania.* See Reports, p. 302.

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10. *Eighteenth Report on the Zoology of the Sandwich Islands.* See Reports, p. 301.

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11. *Interim Report on Zoology Organisation.*

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12. *Report on the Occupation of a Table at the Marine Laboratory, Plymouth.*—See Reports, p. 304.

13. *Report on Experiments on the Development of the Frog.* See Reports, p. 304.

14. *A recent Visit to the Ceylon Pearl Banks.* *By* Professor W. A. Herdman, *F.R.S.*

The author gave some natural history notes on the life and surroundings of the pearl-oysters from observations made during a recent visit to the Ceylon pearl banks. These dealt with (1) the kind of ground the oysters live upon and the objects to which they are attached; (2) the oyster-eating fishes and other enemies that may affect the life of the oyster; and (3) the different types of oyster that occur and the question of their constancy on certain grounds.

15. *Wild Ancestors of the Domestic Horse.* *By* Professor J. Cossar Ewart, *F.R.S.*

MONDAY, SEPTEMBER 7.

Joint Discussion with Section K on Determination of Sex. *Opened by* L. Doncaster, *M.A.*

Until rather recent years there was the utmost diversity of opinion as to the determination of sex. Some regarded it as depending on nutrition, others on the age of the parents or maturity of the germ-cells, some as depending wholly on the egg, and others, again, on the spermatozoon. Gradually, however, a certain amount of order has emerged from this chaos. In the first place, the facts of parthenogenesis made it clear that in many cases at least the sex was determined irrevocably in the egg before segmentation; and the same thing was shown by such instances as *Dinophilus* and certain mites, in which the eggs which will yield females are larger than those producing males, although both need fertilisation. The bee and those animals which behave similarly, on the other hand, indicate that sex may be modified by the spermatozoon, for in them virgin eggs yield males, fertilised eggs females; but here, again, no treatment after fertilisation will turn a female into a male or the reverse. It may therefore be regarded as established in very many cases that from the moment of fertilisation at least, and sometimes in the unfertilised egg, the sex is irrevocably determined.

The problem had reached this stage when M'Clung, Wilson, and others discovered that in certain insects the males and females contain different numbers of chromosomes in the germ-cells before maturation, the females having an even number and the males one less. After maturation there are two kinds of spermatozoa, one containing the same number as the mature egg, and the other having one chromosome missing. It was at first suggested that at fertilisation the spermatozoon having the larger number caused the egg to develop into a female, that with the smaller number male; but Wilson's later suggestion is that there is selective fertilisation, that the eggs are either male or female, and that male eggs are fertilised by spermatozoa having no heterochromosome, female eggs by those which have it. Morgan has recently found that in a species of *Phylloxera* there are two kinds of spermatids, one of which has one chromosome more than the other. Those with the smaller number degenerate; those with the larger develop into functional spermatozoa, and all fertilised eggs become females.

Recently important evidence has been obtained from breeding experiments with *Lepidoptera*, fowls, &c. In the moth *Abraxas grossulariata* there is a rare variety, *lacticolor*, which is found usually only in the female. It is a Mendelian recessive, so that when paired with a typical male all the offspring are typical *grossulariata*. The various possible matings give the following results:—

Lact. ♀ × *gross.* ♂ gives ♂ *gross.*, ♀ *gross.*
Heterozygous ♀ × heterozygous ♂ gives ♂ *gross.*, ♀ *gross.*, ♀ *lact.*
Lact. ♀ × heterozygous ♂ gives ♂ *gross.*, ♂ *lact.*, ♀ *gross.*, ♀ *lact.*
Heterozygous ♀ × *lact.* ♂ gives ♂ *gross.*, ♀ *lact.*
Lact. ♀ × *lact.* ♂ gives ♂ *lact.*, ♀ *lact.*
Wild *gross.* ♀ × *lact.* ♂ gives ♂ *gross.*, ♀ *lact.*

There are here two results of great importance—first, that *lact.* ♂ can only be produced from the mating *lact.* ♀ × heterozygous ♂, for the converse mating (heterozygous ♀ × *lact.* ♂) gives all ♂s *gross.*, all ♀s *lact.*; and, second, that although *lact.* ♀ × wild *gross.* ♂ gives all offspring *gross.* of both sexes, yet the converse cross wild *gross.* ♀ × *lact.* ♂ gives all ♂s *gross.*, all ♀s *lact.* This last result proves that wild and apparently pure *gross* ♀s are really heterozygous in respect of the *lacticolor* character.

The explanation appears to be as follows: The sex determinants behave as Mendelian characters, maleness and femaleness being allelomorphic with one another and femaleness dominant. All females are heterozygotes, carrying recessive maleness, and producing male-bearing and female-bearing eggs in equal numbers; all males are homozygous, carrying only maleness and producing only male-bearing spermatozoa. Further, the *grossulariata* character cannot be borne by a female-bearing gamete. Then if G stands for *grossulariata*, L *lacticolor*, ♂ male determinant, and ♀ female determinant, we shall get the following results:—

Mating.	Constitution.	Gametes.	Offspring.
Female *lact.*	LL ♀ ♂	L ♀, L ♂	L ♀ G ♂ = *gross.* female.
Male *gross.*	GG ♂ ♂	G ♂, G ♂	L ♂ G ♂ = *gross.* male.
Female *lact.*	LL ♀ ♂	L ♀, L ♂	L ♀ G ♂ = *gross.* female
Male heterozygote	GL ♂ ♂	G ♂, L ♂	L ♀ L ♂ = *lact.* female.
			L ♂ G ♂ = *gross.* male.
			L ♂ L ♂ = *lact.* male.
Female *gross.*	GL ♀ ♂	L ♀, G ♂	L ♀ L ♂ = *lact.* female.
Male, *lact.*	LL ♂ ♂	L ♂, L ♂	G ♂ L ♂ = *gross*, male.

We can prove experimentally that all *grossulariata* females in this case are heterozygous in respect of the *lacticolor* character, and that normal wild males are homozygous and do not bear *lacticolor*, so that the variety can never appear under ordinary circumstances. The simplest explanation that has been offered for this fact is the one suggested, that females are also heterozygous in respect of sex-determinants, while males are homozygous, and that in gametogenesis there is repulsion between the female determinant and the *grossulariata* determinant, so that the two cannot be borne by the same gamete.

The following Papers were then read:—

1. *The Early Development of the Marsupialia. By* Professor J. P. Hill.

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2. *The Gastrulation and Formation of Layers in Amphioxus.* *By* Professor E. W. MacBride, *F.R.S.*

Two main types of theory as to the method in which the germinal layers are formed in Amphioxus have been advanced. These are (1) That the invagination which changes the blastula into a gastrula is a simple process, and that the whole of the invaginated layer is endoderm, from which notochord and mesoderm take their origin by a process of folding. (2) That the invagination is a double process; on the ventral side of the blastopore the unfolded cells are true endoderm, whilst on the dorsal side they are ectoderm; the ectodermic roof of the archenteron becomes completely used up in the formation of notochord and mesoderm, which become cut out of the wall of the archenteron by the upgrowth of the true endoderm cells at the side.

The first view was put forward by Kowalevsky and Hatschek and was supported by Samassa and myself, while the second view was advocated by Livoff and has recently been strongly supported by Cerfontaine. Morgan and Hagen take an intermediate view, asserting that there is a difference between the cells on the dorsal and ventral sides of the archenteron, but they do not assert that the dorsal cells are ectoderm. The object of the present communication was to present the results of a careful re-examination of the whole subject.

The starting-point may be made from a flattened blastula. On the flat side are some larger cells, which have been rashly identified with the whole endoderm, but which pass by imperceptible gradations into the cells of the rounded side, and which have yolk-granules of the same size and character as those of the other cells. Invagination commences at one edge of the flat surface by the establishment of a growing point, where cells are added to both inner and outer layers, accompanied by an invagination of the newly formed inner cells, which gradually involves the larger cells mentioned above. The impression is given that these larger cells are passively dragged in by the movement of the active cells. The growing point becomes the dorsal lip of the blastopore, and eventually a cylindrical gastrula, with a wide terminal blastopore, is formed. The future neural plate is indicated by a flattening, and in this way we are enabled to identify the growing point mentioned above with the dorsal lip of the blastopore. A difference between the nuclei of the outer ectodermal cells and those of the invaginated cells now becomes observable, the passage from one to the other kind taking place sharply at the blastoporal lips. No difference whatever, either in size or quality of yolk-granule, is observable between the cells forming the roof and those forming the floor of the archenteron.

Subsequently a new growing point is formed at the ventral lip of the blastopore, and by the activity of this the blastopore becomes narrowed and forced up on to the dorsal surface. Then the first indication of the folds to form mesoderm and notochord are seen, and then, and then only, in consequence of a disappearance of yolk-granules, some difference becomes observable between floor and roof of the archenteron; but this difference is a secondary, not a primary, histological differentiation. The mesoderm originates from a dorsal lateral fold of the endodermic wall, which becomes cut into anterior and posterior halves by the growth of a septum. Both halves of the fold remain open into the gut. The front half becomes, however, eventually closed off and forms the first myotome on each side, which is different from the rest, both in its shape and history, and corresponds to the mandibular head-cavity of other vertebrate embryos and to the collar cavity of Balanoglossus. The posterior division corresponding to the lateral plate of mesoderm of other vertebrate embryos, and to the trunk cavity of Balanoglossus, retains its connection with the gut for a longer time. From its front end the somites of the body are cut off. The head cavities arise later still as a single median evagination of the anterior gut-wall, agreeing in this respect with Balanoglossus and the Elasmobranch embryo. Before this outgrowth separates from the gut, it begins to be divided into right and left halves of different character.

With some slight modifications, therefore, the simple view of the development of Amphioxus taught by Kowalevsky and Hatschek is to be maintained, and the development of other vertebrates ought to be interpreted in terms of the development of Amphioxus, not *vice versa*.

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3. *The Evolution of Fishes. By* Dr. A. Smith Woodward, *F.R.S.*

TUESDAY, SEPTEMBER 8.

Joint Meeting with Section I.

The following Papers were read:—

1. *Binomics of Tsetse Flies.* *By* R. Newstead.

It is just seventy-eight years since Wiedemann published the first authentic description of a tsetse fly, and it was this author also who in 1830 erected the genus *Glossina*, basing his description on a single specimen of *G. longipalpis*, captured at Guinea or in the maritime region of West Africa, and now preserved in the Natural History Museum at Vienna. In the same year, though at a somewhat later date, Robineau-Desvoidy overlooked Wiedemann's work and erected the genus *Nemorhina* for the reception of *Glossina palpalis*, which is now known as having the widest distribution of all the members of this remarkable genus. In 1849 Mr. F. Walker described *G. fusca*, and in 1850 Professor Wedgewood gave the diagnosis of *G. morsitans* and *G. Tachinoides.* Austen described *G. pallidipes* and Bigot *G. pallicera.* Recently Mr. Newstead has also described a species taken at Leopoldville by (the late) Dr. Dutton and Dr. J. L. Todd. Referring to the life-history of these flies, Mr. Newstead pointed out that a single female produced one fully matured larva at a time, and at intervals of from four to ten days. The habitat for the pupa was first discovered by Dr. Bagshaw among the roots of banana, but the author had subsequently found them, an inch to an inch and a half below the surface, among the fallen leaves of a deciduous shrub belonging to the genus *Alophyllus*, as well as between the buttressed roots of a species of ficus, &c. The distribution, habitats of the flies, and other matters were dealt with, special reference being made to the structural characters of these insects.

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2. *Cultures of Amœbæ.* *By* J. W. W. Stephens, *M.D.*

The medium at present in use for the cultivation of amœbæ is that devised by Musgrave and Clegg, viz.:—

Agar	20·0 grammes.
Nall	0·3–0·5 ,,
Beef extract	0·3–0·5 ,,
Distilled water . .	1000 c.c.

The alkalinity should be one per cent. to phenopthaleïn. The optimum temperature is 20°–25° C. No growth is obtained under anærobic conditions.

Mode of Isolation of Amœbæ.—The fæcal material is streaked on agar poured out in plates in the ordinary way. Some authors advise *first* smearing the plate with cultures of various bacilli obtained from the stool in question. The reason for this latter procedure is that amœbæ are symbiotic with bacilli, and a selection of bacilli is offered in order to increase the chance of a successful result.

Pure Mixed Cultures.—Starting from an impure culture of amœbæ and bacilli obtained from the gut, the plate is examined with a low power of the microscope and a single *isolated* amœba is selected. This is then enclosed with a ring of carbol-vaseline (Walker), so as to prevent the amœba wandering out or others wandering into the ring. When this amœba has sufficiently multiplied it is transferred to another plate, so that we have a culture of one species of amœba with several bacilli (viz., those of the gut). In order to get a pure mixed culture, a pure culture of a particular bacillus (x) is inoculated in concentric rings on a fresh plate; the impure culture is inoculated in the centre, and as the amœba wanders over the plate it leaves behind its bacilli (obtained from the gut) and is found with the periphery of the plate, now, with the pure culture of bacillus (x), giving the pure mixed culture.

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3. *The Action of Atoxyl and Allied Compounds* in vivo *and* vitro. *By* Dr. M. Nierenstein.

Experiments *in vivo* and *vitro* lead to the conclusion that 'Atoxyl'—*p*-aminophenylarsenic acid—combines with the proteins and acts in forms of this combination. Atoxyl does not act on trypanosomes *in vitro.* It is evident from the experiments that this combination takes place through the NH_2 group, and it is never suggested that the arsenic group in atoxyl plays the rôle of the 'antiparasitophoric group' (the 'trypanophobic group' of Moore, Nierenstein, and Todd) when the amido group acts as the 'antiparasito genetic group.' The proteins act as 'mordants.' This explains the observations of Moore, Nierenstein, and Todd. and also of Breinl and Nierenstein, that parasites when they become 'autoxylfast' they only are so for the species and when this character has been acquired. Atoxyl is secreted by the horse, as *p*-aminophenylarsenic acid, *p*-oxyphenylarsenic acid, and arsoxycarbamil. Those compounds are found in the hippuric acid residues which were isolated from the urine by Roaf's methods.

4. *The Morphology of* Piroplasma canis. *By* Dr. A. Breinl *and* E. Hindle.

Piroplasma canis is the cause of the disease known as 'malignant jaundice,' which affects dogs in many parts of the world (India, Cape Colony, the Levant, &c.) The infection is naturally transmitted by ticks (*Hæmaphysalis leachii,* &c.), but in the laboratory the strain is easily kept going by means of simple blood inoculation from dog to dog. In young animals the parasites usually appear in the peripheral blood about two days after inoculation.

At early stages of the infection the parasites are large, amœboid, and very vacuolated, and usually possess only one nucleus. These forms multiply by simple fission, or, occasionally, by means of budding. The large nucleus soon buds off a small nucleus, which often remains connected with it by a fine chromatic line. These bi-nucleate forms divide so as to give rise to two pear-shaped forms.

At later stages of the infection, when the parasites multiply very rapidly, the above described processes become somewhat irregular, owing to the extreme rapidity of division. The pear-shaped division differs somewhat from that occurring at earlier stages of the infection. Nearly all these latter forms are binucleate, and are usually somewhat smaller than the early forms.

Occasionally the ordinary free parasites develop a very fine flagellum.

At certain stages of the infection (before the rapid increase in the number of the parasites) we have been able to trace the development of large flagellate bodies. The two nuclei of an ordinary intra-corpuscular parasite swell up, and the result in form somewhat resembles Leishmania. These parasites become free, increase enormously in size, and develop two flagella; they eventually assume one of the two forms described below.

1. The most frequent are large, elongate bodies, in which the large nucleus appears to empty out its chromatin and become merely an achromatic residuum. A varying number of small chromatic masses occur scattered through the protoplasm.

2. These are large round forms, with a large nucleus and a varying number of small nuclei. The large nucleus consists of a densely staining karyosome surrounded by a lightly staining area.

Various stages in the development of these flagellate forms may be seen in cultures of *Piroplasma canis.* We have been unable to follow their subsequent development.

5. *The Pharmacological Treatment of Trypanosomiasis.* *By* Professor B. Moore.

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6. *The Life-history of Trypanosomes in relation to the Diseases they produce.* *By* J. E. S. Moore and Dr. A. Breinl.

T. gambieuse undergoes a complete life-history in the animal organism. The life-history takes place in three phases—multiplication, then an inter-action between nucleus and extranucleur centrosome, then the formation of latent bodies, *i.e.*, small round bodies with typical tryp-nucleus and vacuole. From this the new generation of Trypanosomes develops.

T. equiperdium undergoes a similar, somewhat modified, life-history.

T. Lewisi develops in a somewhat similar way.

The authors suggest that from the similarity of the life-history with the life-history of Crithidia described by Patton, Crithidia have a distinct relation to Trypanosomes.

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7. *Hæmatozoa from some Ceylon Reptiles.* *By* Muriel Robertson, *M.A.*

The parasites discussed in this paper were treated according to their occurrence in the vertebrate host.

Among tortoises *Nicoria trijuga* and *Emyda vittata* were very generally found to be infected. *Nicoria trijuga* shows *Hæmogregarina nicoriæ* (Castellani and Willey). Multiplication occurs in the vertebrate host. The transmitting host is a water-leech, a species of Branchellion. The Hæmogregarines become motile in the alimentary tract of the leech.

Emyda vittata harbours *Trypanosoma vittatæ* (Mihi) and *Hæmogregarina vittatæ* (Mihi). The Trypanosome, both on the slide and in the alimentary tract of the transmitting host, a species of Glossiphonia, divides into four small flagellated individuals with kinetonucleus anterior to trophonucleus. They ultimately develop into slender Trypanoform organisms, the kinetonucleus lying generally immediately in front of the trophonucleus.

Hæmogregarina vittatæ has two forms: (1) Broad massive form, showing reticulate protoplasm and delicate loose nucleus; the larger forms have two red-staining plastid-(?)like bodies at one end. (2) Recurved form, with pale protoplasm and dense nucleus; the two limbs are equally long. Schizogones occur in the spleen and liver; eight reproductive bodies are formed; these are enclosed in pairs in a delicate boat-shaped capsule. Transmitting host apparently Glossiphonia, as above.

Among lizards, *Hemidactylus leschenaultii* and *H. triedrus* harbour a number of different parasites.

H. leschenaultii has four different species:—

1. *Hæmogregarina leschenaultii* (Mihi). This shows two free motile forms always present in the blood, and two endo-corpuscular forms. Schizogones occur in the blood. Transmitting host not known.

2. *Trypanosoma leschenaultii* (Mihi). The size of this form varies very much. Transmitting host not known.

3. *Trypanosoma pertenuis* (Mihi). This trypanosome is also present in *Hemidactylus triedri*; it is a very delicate form with a small circular nucleus, lying about half-way from the non-flagellate tip; the kinetonucleus is very minute, and lies immediately behind the trophonucleus.

4. *Hæmocrystidium Limondi* (Castellani and Willey), 1904.

Hemidactylus triedri harbours, as well as *Trypanosoma pertenuis, Hæmogregarina triedri* (Mihi). This form has a double capsule, a loose deeply-staining outer sheath, and a delicate inner capsule with an operculum.

Among snakes the common rat-snake, *Zamenis mucosus* and *Chrysopelea ornata*, both showed the same species of Hæmogregarine—a form with highly refractive capsule thickened at both ends.

Hæmogregarines were also found in the cobra and *Python reticulatus.* The form in the python is very actively motile in its free phase.

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8. *On the Structure of* Dendrosoma *radians.* *By* Professor Sydney J. Hickson, *M.A., F.R.S., and* J. T. Wadsworth.

The bodies described by Kent as the 'exogenously produced germs' of *Dendrosoma* are epizoic, or possibly parasitic, Acinetaria belonging to the genus Urnula. The only true reproductive bodies of the species are the so-called 'internal buds,' or gemmulæ, first described and correctly figured by Levick. The meganucleus is a long strap-like body in the axis of the base and branches, but it is in some respects incorrectly drawn in all the figures that have been published. It never, or very rarely, extends as far as the distal extremity of the processes, and some of the shorter branches have no meganucleus in them at all.

In many specimens the micronuclei can be clearly seen. When they reach their full size they are 4 μ in diameter. In the division of the micronuclei a spindle is formed 24 μ in length. The chromosomes are very numerous and minute. There are no centrosomata. Conjugation has not yet been observed in the genus.

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9. *On some Points connected with the Vetebrate Alimentary Canal, more particularly in that of the Higher Mammalia. By* Professor Alexander Fraser.

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10. *The Maxilla and Palatine in the Mammalia.* *By* Professor Richard John Anderson, *M.D., M.A.*

The extent of the palate process and its relation to the horizontal plate of the palatine are the chief points considered. The following table gives the measurements of the inter-palatine suture and the inter-maxillary suture. The position of the posterior border of the hard palate has been examined, also the length of the maxilla along the molar line, and in some cases the distance of the summit of the frontal process of the maxilla from the anterior part of the maxilla below and from the tuberosity behind. Taking the two latter and comparing with the molar line, the three are very nearly equal in several cercopithecidæ examined. So the first two measurements may be equal and the last different. In the first case the maxilla would be a pyramid on an equilateral base.

The palatine border varies in position at different periods of development.

The formation of the teeth is responsible for much of the change. The horizontal plates of the palatines make up for the altered maxillo-palatine plate. The enlarged back teeth, with the corresponding enlargement of the alveolar process, taken in connection with the extended horizontal palatine plate, are not without significance. It seems that an absorption of lime phosphate from an adjacent portion of bone is the easiest way to obtain this salt for new ossific matter. The thinning or fenestration or vacuolation of a bone might easily serve for this. We find, at all events, extension of the palatines forwards (hystricoidea)—*e.g.*, capybara, hystrix, or backwards (ursidæ); in some mammals fenestration (hares), vacuolation (marsupials). The accompanying table explains itself:—

Mammalian Maxillæ.

——	IP.	IM.	——	IP.	IM.
Cervus capreolus	3	3·5	Dasypus longicaudata	2·5	3·5
Cervus sp.	7	10	Centetes ecaudatus	1·3	3
Antelope sp.	1·5	5	Talpa	3	6
Cephalophus sp.	1	4·3	Erinaceus europæus	1·6	1·5
Bos taurus (alt.)	7	10	Pteropus	1·3	2
Bos taurus (juv.)	4·5	7·5	Capybara	3·3	5·5
Giraffe	3·6	12·5	Hystrix	4·5	4·5
Sus scrofa (last m. not emerged)	5·6	12·5	Ursus americanus	6	3
			Ursus thibetanus	8·5	8·5
Phacochærus	6·5	13	Lutra	2	1·2
Hippopotamus	8·5	—	Cercoleptes	1·8	1·2
Tapirus (3 m. not up)	3·5	15	Hyæna	3·9	3·5
Equus caballus	5·0	15·0	Canis	4	3·5
Elephas	7	—	Tigris	5·5	3·2
Hyrax	1	1·5	Haliarctos	4	6
Manatus	—	12	Phoca	1·8	3
Halichærus	3	—	Papio	1·8	3·8
Ovis	2	5·2	Gorilla	1·7	6
Manis	1·8	2·5	Phascolomys	2·2	4·6
Myogale	1	1·2	Homo	1·5	2·9
Kangaroo	9	3·8	Indris	0·5	1·9

11. *The Epiphyses of Long Bones (chiefly in Sauropsids).* *By* Professor R. J. Anderson, *M.D., M.A.*

The epiphyses of the long bones in man and mammalia attract the attention of every student, who in human anatomy learn that the epiphysis first to ossify is last to unite with the shaft, and the nutrient artery is directed to the first joining end, with one exception. The epiphyses in Sauropsids are rarely noticed and not often referred to. The large cartilaginous extremities of avian long bones are noteworthy. Ossific deposit in these is rarely observed. There seem to be vicarious ossific deposits in birds and in tortoises, owing to the cessation of motion in certain regions. It is not always easy to get the most satisfactory period in all birds. Mr. F. G. Parsons says that the upper end of the tibio-tarsus in Ratitæ and Gallinaceæ is the only example of true epiphysis in birds. This observer puts this epiphysis to the credit of the ligament attached there. The transition from tendon to cartilage and cartilage to bone is easy. The cartilaginous epiphysial cones in the pigeon may be compared with the bony epiphysial cones of the Sauropterygia. The tips of the former get gradually ossified. Calcification takes place in most anura. A true bony deposit may take place, as in mammals and some reptilia (Parsons). It seems probable that the sub-periosteal plastids may work their way over the epiphysial ends. The lower end of the tibio-tarsus in a turkey in the Galway Museum is not separate. The upper end is bony in part, and this ossific deposit corresponds to the cnemial part. The tarsal part of the tarso-metatarsus is distinguishable. The extremities of the phalanges seem differentiated as if epiphyses were intended. There is a thick cartilaginous end to the ulna above (apparently epiphysial). There is a distal cap on the second metacarpal. Dr. Hugo Füchs has given figures of the humerus of *Varanus*, in which the proximal and distal epiphyses are well seen. The femur of Uromastix, with head and trochanteric epiphyses, as well as distal epiphyses, are given by the same author, who gives sections of the diaphysis and epiphysis to show the nature of the bony epiphysial centres and the cartilage joining them. Füchs mentions the cnemial epiphysis of Rhea, and notes Huxley's reference to it in Struthio. Dollo, indeed, called attention to reptilian epiphyses so far back as 1884. Albrecht also noted these in sections of the upper and lower ends of the femur of *Phrynosoma Harlanii* (Schwalbe's collection). Sauropterygids have large epiphyses in both ends of the femur and humerus (Reynolds) and the humerus in Sauropterygia (Zittel). Anomodontia have also epiphyses (A. S. Woodward). In Monitor both tibia and fibula have proximal and distal epiphyses. The tibia seems to have two proximal and the fibula two (perhaps). There are epiphyses for the head, great trochanter, and lower end of the femur. Shell-like structures, like calcified fibrous tissue, are present near the lower joint. There are epiphyses for the head and tuberosity of the humerus. There are three or four separate shell-like structures below. The radius and ulna have each two epiphyses.

Ossification is favoured amongst other things by rest; the previous deposit of calcareous matter favours this. Cartilage, which is compared with a buffer in the case of the extremities of long bones, will if the cartilage be sufficiently thick, have probably its least mobile part near the central plane, perpendicular, transverse to the lines of pressure. It is possible that further investigation will lead to an increase in the number of Sauropsids known to have epiphyses. (See 'Journal of Anatomy' and 'Anat. Anzeiger,' 8.)

12. *The Development of* Littorina littorea. *By* W. M. Tattersall.

13. *The Digestive Enzymes of Invertebrates.* *By* Dr. Herbert E. Roaf.

The presence of various hydrolytic enzymes has been sought for in a number of invertebrates. Methods used. Protein digestion by total nitrogen determinations after precipitating by trichloracetic acid, and by congo red fibrin.

Hydrolysis of polysaccharides and saccharose by coloration with iodine and reduction of alkaline copper solution.

Hydrolysis of maltose and lactose by Barfoed's reagent.

Lipase and rennin by litmus milk.

Fibrin ferment (?) by oxalated plasma from pig's blood.

Protein digestion at different temperatures showed, in practically all cases, increase in activity up to 40° C.; and with varying amounts of acid or alkali it was found that the maximum of digestive activity occurred with lower strengths than are necessary for mammalian pepsin or trypsin.

The enzymes were prepared by treating the fresh minced tissue with an equal weight of glycerine, and after keeping for some time the extracts were strained through cotton. Certain of these extracts were precipitated by alcohol, and the coagulum extracted with water. The method of preparation appeared to affect the nature of the proteoclastic enzyme found.

The following results were obtained, using glycerine extracts of fresh tissues. Protein digestion by nitrogen determinations:—

Animal and organ	'Peptic'	'Tryptic'	Lipase	Starch-splitting	Glycogen-splitting	Invertase	Maltase	Rennin	Fibrin ferment (?)
Digestive gland of *Cancer pagurus*	0	+	+	+	+	+	+	+	0
Visceral hump of *Patella vulgata*	+	0	+	+	+	+	+	+	+
Intestine of *Echinus esculentus*	+	0	+	+	+	+	+	+	+
Disc of *Ophiocoma nigra*	+	+	+	+	0	+	—	+	?
Asterias rubens pyloric cæca	+	+	+	+	—	—	—	digested	?
Stomach	0	0	—	0	—	—	—	—	0
Mesenteric filaments of *Tealia crassicornis*	0	+	+	0	0	0	—	+	+
Alcyonium digitatum	+	0	0	—	—	—	—	?	+
Cliona celata	+	0	0	0	—	—	—	?	0
Cellaria fistulosa	+	0	—	+	—	—	—	—	—

Watery extracts from the alcohol coagula of the glycerine extracts gave the following results. Protein digestion by congo-red fibrin:—

Animal and organ	'Peptic'	'Tryptic'	Lipase	Starch-splitting	Glycogen-splitting	Invertase	Maltase	Lactase	Rennin
Digestive gland of *Cancer pagurus*	0	+	–	+	+	+	+	+	–
Visceral hump of *Patella vulgata*	?	+	+	+	+	+	+	+	+
Liver of *Pecten opercularis*	0	+	+	+	+	+	+	+	+
Intestine of *Echinus esculentus*	0	+	+	+	+	0	+	+	+
Mesenteric filaments of—									
(*a*) *Tealia crassicornis*	0	+	0	+	0	0	+	0	+
(*b*) *Actinia mesembryanthemum*	0	+	0	0	0	0	0	0	+

In addition the crystalline style of Pecten coagulated blood plasma and the liver extracts of the following molluscs gave a doubtful coagulation of blood plasma; *Buccinum undatum, Pecten opercularis, Trochus zizyphinus,* and *Purpura lapillus.*

Section E.—GEOGRAPHY.

President of the Section—Major E. H. Hills, C.M.G., R.E.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address—

The thirty years that have elapsed since the British Association last met in this city of Dublin have seen an obvious and rapid progress in the science of geography, and a steady though perhaps not quite so apparent a change in the character of that science.

In 1878 large parts of the earth's surface still remained untrodden by the feet of a white man; large areas were open to the enterprise and intrepidity of the explorer; large spaces were blank paper upon our maps. Now there is but little of the earth's surface absolutely unknown.

It is not my intention to detain you by any recapitulation of the work of these years to show you how and by whom these areas have been traversed and the gaps in our maps filled in. I intend rather to speak of the present and of the future work of the geographer, and to do this to any advantage we must at the outset recognise the change that has taken place in the nature of his task, and the fact that the days of individual exploration are over, never to return. We must recognise that sporadic, unorganised effort must be and is being replaced by organised, systematic work, and that the scientific traveller of the last century, with his rough map-making equipment, his compass, watch, and sextant has yielded his place to the scientifically equipped survey-party with their steel tapes, theodolites, and plane tables.

The theme is not a new one to this Section. I find on referring to the transactions of past years that in 1902, at the Belfast meeting, Sir Thomas Holdich, the President of Section E, said: 'We find those spaces within which pioneer exploration can be usefully carried out to be so rapidly contracting year by year as to force upon our attention the necessity for adapting our methods for a progressive system of worldwide map-making, not only to the requirements of abstract science but to the utilitarian demands of commercial and political enterprise.'

These words express succinctly the ideas that I wish to take as the text of my address to-day. I am, however, not ambitious enough to attempt to cover the whole surface of the earth in the brief review that I intend to put before you of the progress of scientific survey. Rather I wish to restrict our outlook to that section of the work in which we may all be considered as having a direct personal interest—namely, the survey of the British empire, especially those lands under the more immediate tutelage of the Government of this country. Let it not be thought, however, that while we for the moment pay little attention to the regions lying outside this definition, we are supporting the fallacious idea that the survey of any part of the earth can be considered apart from the survey of the surrounding country. With the possible exception of the case of an oceanic island such an assumption would be an erroneous one. Our British empire is so widespread and our possessions are so often in close and intricate juxtaposition with those of other nations that there is in this work large scope, and indeed necessity, for international co-operation. Examples of this will occur to us in the course of our review. We shall thus see that in addition to the obvious connection which the geography of our empire has with that of other countries there is an even closer connection in the methods of manufacture of that geography, which methods we summarise under the general term of survey. One of the root ambitions of the scientific surveyor is to determine the exact figure of the earth, an operation for which observations spreading over a large area of the earth's surface are demanded. In fact we may truly say that the problem of the earth's shape will not be completely solved until the whole surface is known to the surveyor. This is, therefore, pre-eminently a problem for international solution.

Before proceeding to the consideration of our special subject, the survey of the British empire, it will be interesting to interpose a few remarks on the questions of the utility and origin of national surveys in general. We may first note the somewhat curious fact that the production of a map of a country, useful as such a work is for many purposes, has almost always been embarked upon because the imperative necessity of maps of the theatre of operations in war has been brought home to the people and Government of a nation. Thus the ordnance survey of England had its first beginning in a military map of the highlands of Scotland, commenced in 1747, intended to facilitate the operations of the troops under the command of the Duke of Cumberland. It was not till many years later that the systematic triangulation of the country was undertaken, a work which was initiated partly for map making and partly for astronomical purposes. There was a consensus of opinion among astronomers that it would be greatly to the advantage of that science if the observatories of Greenwich and Paris could be connected by triangulation and the famous French astronomer Cassini, in October 1783, drew up a memoir to this effect. The arguments brought forward convinced King George III., and he granted a sum of money sufficient to enable the work to be started. This act of royal generosity was recorded by the surveyors in the following grateful terms: 'A generous and beneficent monarch, whose knowledge and love of the sciences are sufficiently evidenced by the protection which he constantly affords them and under whose auspices they are daily seen to flourish, soon supplied the funds that were judged necessary. What his majesty has been pleased to give so liberally it is our duty to manage with frugality consistent with the best possible execution of the business to be done.'

It is worthy of remark that the junction of the triangulation systems of Great Britain and France was not made until 1861 and that the trigonometrical connection of Greenwich and Paris observatories has not yet been completed to the final satisfaction of men of science, a point which we shall have occasion to recur to later.

In France, we may note in passing, the starting of the triangulation had a quite different and quite definite object, the determination of the length of the metre. This unscientific unit of length was fixed as a fraction (1/10,000,000) of the quadrant of the earth's surface between the Pole and the Equator, and to find this quantity it was necessary to measure on the earth's surface as long an arc of the meridian as could be obtained.

In the case of our other great national survey, that of India, its origin is to be found in circumstances somewhat analogous. The Madras Government, owing to the success of the British arms in the Mysore campaign, found itself with a great accession of totally unsurveyed country in the middle of the Peninsula, while at the same time there were only in existence the roughest sketch-maps of the older possessions. It was apparent that if any map, of even approximate accuracy, was to be made covering a country of such vast area, it was imperative that the work should be prosecuted upon the most rigorous and strictly scientific basis. The general lines upon which it should be undertaken were laid down in February 1800 by Brigade-Major Lambton, who addressed a letter to the Madras Government advocating a mathematical and geographical survey of the peninsula.

In this letter he discussed the principles upon which such a survey should be based. He dismissed astronomical fixations as not providing the requisite degree of precision, observing that such determinations of position are liable to great inaccuracies, 'three, four, perhaps ten minutes,' and proposed a triangulation emanating from a measured base line checked by similar base lines at intervals. He recognised that the figure of the earth and lengths of the polar and equatorial radii were not then known with the precision necessary for fixing the spheroidal co-ordinates of the trigonometrical stations of a survey covering such a large area of the earth's surface, and that a geodetic survey was therefore necessary *pari passu* with the geographical survey. He had an impression, how derived it is not now possible to say, that there was a sudden abnormal diminution of the force of gravity at the latitude of 10° north, and consequently that 'a degree on the meridian from that parallel to the Equator must be very short compared with a degree to the northward of 10°.' He observed that it would be necessary to 'attend to this circumstance,' which he characterised as important both from the map-making and from the rigorously scientific point of view. He added: 'I shall rejoice, indeed, if it should come within my province to make observations tending to elucidate so sublime a subject.'

In a similar case, occurring in recent years, the outcome has not been so satisfactory. It will be within the recollection of all here how at the time of the South African war the public at home learnt with shocked surprise that there were no maps in existence of a colony which had been under the British flag for a long period of years. To those who knew the facts this was, naturally, no matter of surprise; but it was earnestly hoped by many that this grave deficiency thus revealed by the stress of war would be remedied by quiet work in the time of peace and that, at the conclusion of the military operations, the foundation should be laid for a federal survey department of British South Africa comparable with, though on a more moderate scale than, the Survey Department of India. This hopeful scheme, which it may be recorded very nearly came to fruition, ultimately found political conditions too adverse, and had to be indefinitely postponed. An army engaged in field operations in the north of Natal now, or in fact at any time for an indefinite number of years in the future, would find the country nearly as mapless as it was found by Sir R. Buller in 1900.

In this short recital of the determining causes which have in the past led to the initiation of national surveys, it will have been noticed that no allusion has been made to what we should now perhaps consider the main utility of a map—namely, its value for all purposes connected with the ownership, development, and taxation of land. When the ordnance surveys of Great Britain and Ireland were originated there was little thought of this use, and it was not till long after that period, when the enormous deficiencies of the existing property plans were revealed by the Tithe Commutation Acts and by the railway boom, that the value of a national survey for preparing a cadastral or large-scale property map of the country was recognised and acted upon. Now this is often the ostensible object for embarking upon a regular survey. It is fully recognised that, especially in the case of a country undergoing rapid development, which is fortunately true of many of our oversea possessions, the provision of an accurate land map is of prime necessity both to the private or corporate landowner and to the State.

Neither were any of the early surveys undertaken for the purpose of mutual delimitation of international boundaries; a necessity which has in recent years been the stimulating cause for many pieces of valuable survey work, especially in Africa.

The other manifold uses of a map are familiar to all of you and we need not pause to enumerate them. We may admit the fact that the adequate mapping of its territories is recognised as one of the duties of a civilised State. Let me now turn to the main subject of this address—the inquiry as to how far this duty is performed by us, what shortcomings we can perceive, and what suggestions we can offer for the future.

Two years ago this task would have been a difficult and laborious one. Now it is greatly facilitated by the issue from the Colonial Office of those excellent little volumes, the reports of the Colonial Survey Committee.

This body has been in existence since August 1905, and has published three annual reports. The Committee is therein defined as an advisory one formed at the instance of the Secretary of State for the Colonies to advise him in matters affecting the survey and exploration of British colonies and protectorates, more especially those in tropical Africa. It is not at present an executive body, that is to say it has at its own disposal no grant of public money or other funds; whether it will ultimately develop into such is a question that the future alone can answer. Even thus limited in scope and powers it has, however, already worked a notable improvement—firstly, by laying down authoritatively some of the more salient conditions that ensure the efficient and economical expenditure of whatever funds may be available, and by pointing out the disastrous extravagance of unsystematic and unmethodical work; secondly, by insisting upon uniformity where uniformity is essential, such as in matters relating to the style, projection, scales, and sheet-lines of the maps produced, while leaving the utmost latitude as to methods, these being selected in each case to suit the very divergent nature of the country met with. It results from this that any two small portions of the map of Africa, say, for instance, one sheet of the dense forest region of the Gold Coast and another of highland country of East Africa, though 3,000 miles apart and executed at different times by a different staff, will match each other in general character, and will ultimately be found to fit exactly into their places as constituent parts of a great map of the country. Thirdly, we may reckon the mere fact of publicity in these matters as of no mean advantage. Though, as in the case of many other Government publications, this report is not as widely read as its merits deserve, yet it is all to the good that the information is there ready and available for anybody who has the curiosity to consult it. I therefore welcome the opportunity of drawing your attention to this volume.

In entering upon the discussion on the survey of British Africa, the first point that meets us is the geodetic basis of the whole work; upon what do the actual positions depend? In other words, to put the matter more familiarly, how are we to provide that every isolated piece of the map will exactly fit into its proper place? The only method for ensuring this is by basing all our surveys, ultimately, upon a skeleton or framework of geodetic or primary triangulation executed with the utmost attainable precision. Such a skeleton, or rather backbone, will eventually exist in Africa in the shape of the meridional arc, or chain of triangles, along the thirtieth meridian, running right through the country from north to south, and ultimately joining on to the great arc observed by the famous astronomer Struve. This originally extended from the mouth of the Danube to Hammerfest, in Norway, an amplitude of $25\frac{1}{2}°$ of latitude. To prolong it southward, passing up the Nile Valley, through the heart of tropical Africa, across the Zambezi River, and terminate it at the southernmost point of the continent, is a magnificent conception due to Sir David Gill, to whose energy and enterprise the actual execution of considerable sections of the undertaking must also be ascribed.

At the present time the chain has been completed from the south to within seventy miles of the southern end of Lake Tanganyika, a distance of about 1,700 miles. At Lake Tanganyika it will enter into German territory. The German Government, fully recognising that the project is not only of great theoretical interest, but also of immediate practical value, are already taking steps to start work on their own section, from the south of Tanganyika up to the parallel of 1° south latitude. From 1° south, northward to about $1\frac{1}{2}°$ north, the arc lies near the boundary between the Congo Free State and the British Protectorate of Uganda. An International Commission is at present engaged in the survey of the boundary region, and Sir D. Gill, ever ready to seize an opportunity of forwarding the work he has at heart, succeeded in raising sufficient funds, partly from the Treasury and partly by grants from a few leading scientific societies, to enable an observer to be sent out with this Commission to carry the arc over this section. North of this point the line comes into the territory of the British Soudan, and traversing this eventually reaches Egypt proper. Here it comes into the charge of Captain H. G. Lyons, the director of the Survey Department of Egypt, under whose care its interests are safe.

It will thus be seen that while the actual completion of the whole chain is as yet somewhat remote, we are in the satisfactory position of being able to say that, as far as the section lying on the continent of Africa is concerned, there is no portion of which there is not a reasonable probability that it will be finished within a measurable period. With regard to the section joining Africa and Europe the position is not so happy. This will run through Palestine and Asia Minor and therefore lies in Turkish territory. It is not likely that the Turkish authorities either will or could carry out such a work; in fact, seeing that even when completed it would be totally useless to them, it would be hardly reasonable to expect them to do so. It must, therefore, presumably be a matter for international co-operation. One point may be mentioned with regard to the exact route of this connecting section. Sir D. Gill, in his Report on Geodetic Survey of South Africa, 1896, said: 'By an additional chain of triangles from Egypt along the coast of the Levant, and through the islands of Greece, the African arc might be connected by direct trianglation with the existing triangulation of Greece, and the latter is already connected with Struve's great arc of meridian which terminates at the North Cape in latitude 71° N. The whole arc would then have an amplitude of 105°.' This, however, gives rather a poor connection with the European triangulation. The South Albanian series has a much higher average error than either Struve's original work or any part of the African series. This portion would consequently be a weak link in the geodetic chain, and it would be better to avoid it altogether by carrying the line along the coast of Asia Minor to Constantinople, and then up the east side of Turkey to the mouth of the Danube.

When we look back a few years and call to mind the prominent part that this country has taken in the survey of Palestine—I need only mention in this connection the names of Kitchener, Warren, and Conder—we cannot avoid a feeling of regret that we are not ourselves in a position to take the whole execution of this section of the line upon our shoulders. I am too well aware of the many urgent claims upon the Treasury to suggest that it is possible that they would be prepared to incur such a charge; but supposing, for the moment, that part of the necessary funds could be provided from other sources, I think we may fairly urge that it is our duty to contribute a substantial monetary grant towards the furtherance of an end so desirable and so practically useful.

The difficulty of obtaining money for geodetic work, the benefit of which is not immediately apparent to the man in the street, is notorious. Thus Sir T. Holdich, in 1902, said: 'But this accurate framework, this rigorously exact line of precise values which ultimately becomes the backbone of an otherwise invertebrate survey anatomy, is painfully slow in its progress and is usually haunted by the bogey of finance. It does not appeal to the imagination like an Antarctic expedition, although it may lead to far more solid results, and it generally has to sue *in forma pauperis* to Government for its support.' To account for this regrettable, but undoubtedly true, fact two reasons may be adduced. There is, in the first place, the possible ignorance as to the ultimate value of the work; but, secondly, and perhaps not least, there is the fear, not entirely unjustified, that to satisfy the demands of the scientific man is something akin to the operation of filling a sieve with water. It has been so often seen that compliance with one demand only leads to another being made, that we may well sympathise with the holder of the public purse when he draws the strings tight and refuses to pay for an arc along the thirtieth meridian in the fear that directly this is completed he will be asked to pay for one along the twentieth meridian, and then along the tenth, and so *ad infinitum*. It behoves us, therefore, as practical men to make sure that our demands are reasonable and limited to the actual requirements of the case, and where such limits cannot be set we should make this fact clear at the outset. When, however, it is possible to set such limits, we should not hesitate to do so; and in the case of the African arc this latter course is fortunately possible.

If we take the map of Africa we shall see that the arc along the thirtieth meridian passes through, or near, all the colonies of British South Africa, close to British Central Africa, or Nyasaland, through Uganda, and is thus connected with British East Africa, through the British Soudan and through Egypt. There remain absolutely untouched by it only the West Africa colonies—Nigeria, the Gold Coast, Sierra Leone, and the Gambia. These latter will eventually get their geodetic framework by an extension southwards of the French triangulation of Algeria, a work of a high order of precision. We are therefore entitled to say—and I take this opportunity of saying it with all due emphasis—that with the exception of some triangulation to join the West African colonies with the French triangulation, the arc along the thirtieth meridian is the only primary triangulation required for the adequate mapping of the whole of British Africa. The remainder of the geodetic framework can be supplied by ribs of secondary triangulation branching out from the main backbone, such as the line already completed along the boundary between British and German East Africa, passing to the north of the Victoria Nyanza and thence westward to the thirtieth meridian.

You will observe that I here speak only of the triangulation required for mapping purposes, not of that demanded by the geodesist for the study of the figure of the earth. The latter is satisfied only with a survey of the highest attainable precision covering as large an area of the earth's surface as possible, or at all events with arcs, both meridional and longitudinal at frequent intervals. It cannot be other than a very long period before the whole of Africa is surveyed upon this scale of accuracy, and in the meantime we must devote ourselves to the far more urgent duty of mapping the country, leaving the more remote and abstract task to our descendants, well satisfied if in our hands the foundations have been well and truly laid.

Furthermore, as we shall see presently, if we are prepared to recognise as a national duty the minutely precise survey of our own land and of all territories under our flag—and I do not see how any reasonable man can withhold this recognition—then there are duties of this nature lying closer to our hands than any to be found in Africa.

Having thus passed in brief review the ultimate geodetic basis of our African surveys, let us enter more into detail and glance at the actual survey work now in progress in the different regions of the continent.

In British South Africa, as we have already noted, the political conditions are at present unfavourable to any comprehensive scheme of operations. There is however in progress a first-class topographical survey of the Orange River Colony and a reconnaissance survey of Cape Colony. The former is an excellent example of the class of work that can be done by a small military party of the highest technical training working upon systematic lines, and I should like to devote a few minutes to a short description of the methods adopted and of the results obtained.

The survey party consists of two Royal Engineer officers and four non-commissioned officers, the former undertaking the triangulation and the general supervision of the field work, and the latter the plane tabling. The positions are primarily based upon the points of the geodetic survey broken up into a secondary triangulation with sides averaging ten miles. In 1907 the average triangular error of the secondary work was 2·9 seconds of arc, and the greatest linear errors of displacement, as tested by the geodetic triangulation at the end of a chain forty-five miles long, were three feet in latitude and two feet in longitude. The probable error of a trigonometrical height was under a foot. You will see therefore that the accuracy is ample for all mapping purposes, even upon large scales, and the degree of precision is in excess of that demanded for a topographical map on the scale of two miles to an inch. The rate of progress and the low cost of work are, however, no less notable than its accuracy. The actual rate of outturn is about eight square miles per day per man, or for the whole party twenty-three square miles of detail survey per diem, and the number of trigonometrical points fixed about three hundred per annum. The cost works out to about eight shillings per square mile of the completed map, and the whole area of 47,000 square miles will be finished, printed, and published in five and a half years.

These remarkable results are due in a large measure to the energy and organising power of the officer in charge, Captain L. C. Jackson, R.E. The detail survey is done in sheets fifteen minutes square, each non-commissioned officer being given one complete sheet, which he works at until finished. Four such sheets are therefore in progress at any given time, and each sheet takes about six weeks. Seeing the rapid rate of progress maintained it might perhaps be thought that the country is a particularly easy one for the topographer. Such is, however, by no means the case. It is true that there is an entire absence of the surveyor's greatest impediment, large areas of dense forest, but there is much broken and difficult country, rising in places to altitudes of above 7,000 feet.

In Cape Colony the reconnaissance survey is of a somewhat similar character, but owing to the large area of the country and to the small amount of money available the work has perforce to be of a more rapid nature. In Natal, Bechuanaland, and Rhodesia no survey is at present in progress.

Passing northward through Africa, we come to the British Protectorate of Nyasaland, formerly called British Central Africa. Of this country a certain number of maps exist purporting to give topographical detail; but as they are not based upon any framework of triangulation, and as much of the detail only depends upon rough sketches, it is impossible to say how far they can be accepted as correct representations of the ground.

It is most unfortunate that financial considerations prevent the execution of any systematic trigonometrical survey. The absence of such, and the fact that maps are being made which must inevitably be withdrawn and replaced by others in the future, will undoubtedly be the cause of ultimate waste of money.

Passing northward again we come to the large and important protectorates of British East Africa and Uganda, in both of which systematic surveys are in hand. The geodetic framework is supplied by a triangulation along the Anglo-German boundary, connected with chains of triangles along the railway in the neighbourhood of Nairobi. In Uganda proper there is also a triangulation covering a substantial area. As already noted, all this work will eventually be tied into the thirtieth meridional arc, though it is not likely that the final adjustment of geodetic positions thus arrived at will necessitate any substantial alterations upon the maps.

In both protectorates topographical surveys are in hand, and maps on the scale of two miles to an inch will be issued. In British East Africa, under the able direction of Major G. E. Smith, R.E., rapid progress is being made. This topographical mapping is additional to the cadastral maps also in progress in both countries. These latter are required for property purposes, in Uganda for demarcating the estates given over to the native inhabitants of the country under the agreement of 1900, and in East Africa for attachment to title-deeds of lands alienated for farming or stock-raising.

In the Soudan the enormous area of the country—over a million square miles—and the limited funds available have prevented any systematic survey being taken up. A large amount of reconnaissance mapping has been done, and a series of sheets on the scale of 1/250,000 (four miles to an inch) have been published. These are corrected and improved by officers and Government officials as opportunity offers. The energies of the Survey Department are almost entirely spent in meeting urgent local requirements in the shape of cadastral maps of the cultivated areas along the river.

Somaliland, a British protectorate which came into unfortunate prominence a few years ago, is a country of too small value to be worth the cost of any sort of survey, and the only maps that exist are based upon the route sketches of travellers and sportsmen and upon the work done by a small section of the Survey Department of India during the military operations five years ago.

Leaving the east side of Africa and turning our eyes westward, we may note that in the colony of the Gold Coast a rigorous survey was rendered imperative by the gold-mining boom of 1901. The work was entrusted to Lieut.-Colonel Watherston, C.M.G., R.E. Owing to the dense forest covering practically the whole country triangulation would have been prohibitive in price and very slow in execution. The initial positions were therefore fixed by a network of long traverses, executed with all possible refinements with steel tapes and theodolites. Astronomical latitudes were observed by Talcott's method at every fifty miles. The errors of misclosure of the traverses proved to vary from about 1 in 2,000 in unfavourable cases to nearly 1 in 6,000—results inferior to triangulation, but at the same time sufficiently accurate to form the basis of a map with no appreciable errors *on the paper*. One great defect of the traverse method of fixing points lies in the practical impossibility of carrying the heights through without occasional checking, either by lines of levels or by trigonometrical observations. Such work makes therefore an imperfect basis for topography, and would only be used when natural features compel its adoption.

Northern Nigeria is a country of enormous area, and, up to the present, of small revenue. It has therefore not been found possible to allocate the funds for any systematic mapping. The existing maps are compilations based upon sketches made by civil and military officers when travelling upon duty and upon the surveys made by the different Anglo-French and Anglo-German boundary commissions. In 1905–6 Captain R. Ommaney, R.E., fixed the astronomical longitudes of fifteen towns by exchange of telegraphic signals with Lagos. With the aid of these values, combined with a number of astronomical latitudes, it has been possible to combine the material into something like a complete map. It need, however, hardly be pointed out that astronomical fixations are liable to large and uncertain errors, due to the variation of local attraction, and cannot attain the precision of even a rapid triangulation. In Southern Nigeria the experience has been somewhat unfortunate. This colony has spent a very substantial sum upon its survey department, and if the work had been properly organised and systematically carried out we should by now be in possession of a complete map of a large portion of the country. Unluckily, the mistake has been made of detaching survey parties for non-geographical purposes, such as the erection of telegraph lines, work doubtless urgently required in the interests of the colony, but not lying within the sphere of a survey department. Thus systematic progress was rendered impossible, and, though isolated pieces of triangulation and long lengths of traverses have been done, no topographical map of any area yet exists.

Of the remaining West African colonies the Gambia river is a narrow piece of land with boundaries running parallel to the river banks, and, except for the actual trade along the river, is unimportant. In Sierra Leone the country in the immediate vicinity of Freetown was surveyed by the colonial survey section, a small party employed by the War Office for the purpose of making surveys of places of special military importance. The map of the remainder of the colony is a compilation based on miscellaneous material.

In the course of this summary of the state of the mapping of British Africa mention has been made of the surveys made by joint commissions appointed for the delimitation of international frontiers. No small part of the existing map is due to work of this class. Thus joint Anglo-French commissions have marked out the frontiers of the Gambia, Sierra Leone, the Gold Coast and Nigeria: Anglo-German commissions the eastern boundary of Nigeria, the boundaries between British and German East Africa, between German East Africa and North-East Rhodesia from Lake Nyasa to Tanganyika, and between Bechuanaland and German South-West Africa; Anglo-Portuguese commissions the frontiers between Portuguese East Africa and North-East Rhodesia and Nyasaland respectively. Useful surveys have also been made in the course of the mutual demarcation of the frontiers between Abyssinia and the Soudan on the west and British East Africa on the south; also of the frontier between the colony of Sierra Leone and the Republic of Liberia.

Important as the work done by these commissions has been, its value would be greatly enhanced if the reports of each commission were published in a succinct and easily accessible form. Such reports would naturally contain a record of the actual frontier as finally ratified, and also a technical account of the survey methods employed. They would thus be of permanent use both to the official or officer on the spot for the easy settlement of any disputes that may arise, and to the chief of any future boundary commission as an aid to the selection of the methods of survey most suitable to the particular country with which he is concerned.

Up to three years ago many of the African protectorates were under the tutelage of the Foreign Office, while the older colonies were under the Colonial Office. The reports of Boundary Commissions are therefore scattered through official documents in the two offices, and are drawn up upon no uniform model. Now that the superintendence of all these territories has been handed over to the Colonial Office, and that body has set itself such an excellent example in the appointment of the Colonial Survey Committee and the publication of its reports, it is greatly to be hoped that they will follow up th good work and systematise and publish all these Boundary Commission reports. If a model for such a publication is desired, I may refer to the account of the demarcation of the Turko-Egyptian frontier between Rabah on the Mediterranean to the Gulf of Akaba, lately issued by the Egyptian survey.

The account which I have endeavoured to give you, short and imperfect as it is, of the present state of the mapping of British Africa will have shown you clearly that there is a large amount of excellent work now in course of execution, and that there has been, especially during the last few years, very considerable progress made towards co-ordinating this work and towards maintaining certain fixed standards of accuracy, rapidity, and economy.

It will naturally occur to you to inquire whether this co-ordination could not advantageously be pressed a step further, and whether all the isolated survey departments, now working in the various colonies and protectorates, could not be amalgamated under one executive head; whether, in fact, a Survey Department of Africa, precisely analagous to the Survey Department of India, could not be formed. The advantages of such a step are obvious, but must not be allowed to blind us to the difficulties. We have, in the first place, the objection to be met that the South African colonies would, under present circumstances, almost certainly refuse to join in any general scheme, and would not consent to any arrangement whereby money raised in one colony would be spent outside its own geographical limits. If however we leave South Africa out of the question, the financial difficulty tends to disappear. Both our East and West African possessions are, in general, not yet in a position to maintain themselves, and are still, and will be for some time to come, partially supported by grants from the Imperial Treasury. To divert a portion of these grants to pay for the maintenance of a survey department would only be a matter of account and could be adjusted so as to cause no hardship to any one colony. There remains the geographical difficulty of space. The fact that the heads of the department would have to keep in close personal touch with countries differing entirely in character, and perhaps three months' journey from each other, does not appear to offer any insuperable objections, and I cannot avoid expressing the hope that it may be found possible at a no very remote date to take some steps in the direction of a consummation which appears so desirable.

In giving my evidence before the Royal Commission on the War in South Africa, presided over by Lord Elgin, I outlined the general features of a scheme under which the Imperial Government would undertake the topographical mapping of all our oversea possessions, apart from self-governing colonies. As on this occasion I was considering the whole question more exclusively from the military side, no reference was then made to the question of cadastral maps, and it was tacitly assumed that these would fall to be constructed by the land office or a land survey department belonging to each separate colony. On the present occasion we are not restricted to the military point of view, but are permitted a wider outlook. Our task is to consider the map in all its aspects, both as regards its method of construction and its ultimate use, whether for military, administrative, engineering, or purely scientific purposes. This enlargement of our scope does not, I think, modify our previous conclusions, and were I now called upon to devise a scheme for the mapping of British Africa, I should base it upon the principle of a central Imperial body for executing the triangulation and topography, leaving the land survey to local organisations.

The arguments in favour of this policy are manifold. As regards the triangulation they hardly require stating. It will be obvious to all that such work must be closely co-ordinated, and that some central, directing head is imperatively called for. The enormous waste of money that is ultimately involved by tolerating imperfect work, of which many examples could be cited, is alone a sufficient justification for holding this view. We may, however, pause to examine a little more closely into the advantages of centralisation as regards one particular operation in a survey. That is the measurement of the initial base line upon which the accuracy of the whole framework depends. This task used to be one of the most laborious and difficult with which the surveyor is confronted. The apparatus employed, some form of compensation bar, was cumbrous and difficult to use, the site selected had to be levelled, and the preparatory alignment carried out with the most scrupulous care. Thus the Loch Foyle base for the triangulation of Great Britain and Ireland was about six miles long, and the actual measurement, quite apart from the time spent on the preparation of the ground, took sixty days, an average rate of work of just over 500 feet per working day.

A few years ago the discovery was made of the nickel steel alloy with a very small or zero coefficient of expansion, the so-called invar. This valuable metal, by abolishing the necessity for any temperature correction, has enormously simplified all physical measurements of length, and, *à fortiori,* those measurements, such as base lines, which are perforce done in the open air and over a large range of temperature. Survey bases are now measured with an invar wire stretched to carefully regulated tension, and either laid along a flat trough, or what appears to give equally good results, hung freely between supports. The gain in precision due to the avoidance of errors of expansion or contraction in the measuring apparatus is substantial, while the gain in rapidity is very great. Thus, as a contrast to the Loch Foyle base, let me give a short account of the measurement of a base in Spitzbergen by the Russian party of the joint Swedish and Russian missions in 1900, extracted from a review already written for the 'Geographical Journal.'

The conditions for accurate work were very unfavourable: no site even approximately flat could be found, and the base was therefore irregular in contour and traversed rough and in some parts marshy ground. The weather conditions were far from ideal. The cycle of operations was as follows: An auxiliary base 175 metres long was measured with Struve's apparatus, twice before the main base measurement and twice afterwards. The two wires used for the main base were standardised on this subsidiary base four times, twice before and twice after use. The main base, 6·2 kilometres long, was measured twice in each direction by each of two wires, eight measures in all. The limit of error in the final value was 17 millimetres—say, one part in 360,000.

The whole of these operations, including the laying out of the standard and the comparison of the wires, were completed in a period of three weeks; Monsieur Backlund, who superintended the actual measurement, left the observatory at Pulkowa on June 11 and returned to it on July 24. It was therefore possible to standardise the wires not only by the check base upon the spot, but also by the permanent standards of the observatory within three weeks of their use for the actual measurement. It need hardly be pointed out that this was eminently favourable to the attainment of the highest exactitude, and we have here a marked example of the value of centralisation. The proposed trigonometrical survey department of Africa would probably find it advantageous to adopt similar procedure, and, instead of trusting a base measurement to a local staff unacquainted with the work, it would send out one or two men of highly trained technical skill equipped with the best apparatus. The money spent in journeys would be more than saved—first, by the unquestionable gain in accuracy and the consequent avoidance of the costly necessity for repeating bad work; and, secondly, by the gain in time, due to the fact that the local staff would not be called upon to learn the use of an unfamiliar set of instruments.

Similar advantages would arise from a partial specialisation of the angular measurements. Thus the first-class observer with a theodolite must possess certain qualities of eyesight, health, and judgment, rarely combined in one individual. When such a combination of qualities is found it should be made the best use of, and a good man should not be wasted on second-class work. At present, upon the system of regarding each colony as an isolated unit, it is not possible to employ every man to the highest advantage, and there are doubtless many examples at present in Africa of able men being set tasks much below the standard of their ability, and, *per contra*, men of no such qualifications being given work beyond their powers. It is only by working with an extended organisation, employing a large staff and responsible for a large area of country, that any approximation can be made towards that ideal wherein every member of the establishment is used to the best advantage according to his special qualifications.

To turn from the triangulation to the question of topography, we shall find analogous arguments in favour of entrusting this work to one central department. Whether we consider the necessity for a uniform system of training for the topographer, or whether, looking at the matter from the other side, we consider the desirability of a close degree of uniformity in the resulting map, we arrive at the same end. Nor need we confine ourselves to theoretical arguments; practical results are before us as examples. It is not possible at the present moment to point out a single case of a thoroughly satisfactory topographical map of any country whatever which has not been executed by men trained in a properly organised survey department or, what is equivalent, in the Corps of Royal Engineers. Examples of failure to accomplish this are numerous. Thus we have the cases of the British Colonies in South Africa before the war; of Canada, where no topographical map existed until two years ago, when the work was taken up by the military department; and of Ceylon, where, in spite of the vast sums spent on survey and the small size of the island, no topographical map of the slightest pretensions to completeness exists of any part of the country.

It may also be noted that, especially in the case of a developing country, it is of enormous advantage that the map shall be begun and finished within some reasonable time. If a long interval elapses between the commencement and the completion, the first sheets are out of date before the last are done and the whole exhibits a most undesirable lack of uniformity.

With a central organisation the mapping of each protectorate can be taken up in turn and dealt with rapidly, thus producing a homogeneous map impossible to a small local body. Upon the converse point, the question as to whether our central department should or should not undertake cadastral survey, the arguments are perhaps not so one-sided. It is, however, quite clear towards which side the balance of advantage tends. Taking into account the intimate connection of the cadastral survey with the system of land holding and land taxation, the fact that these systems necessarily vary and that as a financial matter of account the receipts and expenditure of each colony are separate, it is not difficult to see that the land survey is better left to local control. This would not preclude any particular colony from arranging with the central body for the execution of any definite piece of work of this class, upon terms agreeable to both sides, in a similar manner to that in which cadastral survey is executed by the Indian survey for provincial Governments, and it need hardly be pointed out that the geodetic points fixed by triangulation would in any case be available as a framework for the large-scale map.

The geographical survey of the British Empire, apart from Africa, will not on this occasion detain us long. I exclude from present consideration the great self-governing colonies—Canada, Australia, and New Zealand—and also the whole country lying within the sphere of the survey of India. Ceylon has an elaborate land survey system; and though, owing to past mistakes, the geographical mapping of the island is in a most lamentably backward condition, there are good grounds for hope that this state of affairs will be remedied in the near future. The Malay States, where, owing to the fertility of the soil and the ubiquity of rich tin ore, the land values are high, have the basis of an excellent survey system, and possess a backbone of triangulation which will eventually extend southward to Singapore, and possibly northward to join the Indian series in the south of Burma. Hongkong, including the leased territory on the mainland, is of small area and of no appreciable geographical importance. It has been adequately mapped for military purposes. Of our insular possessions, Mauritius, St. Helena, and (in the Mediterranean) Cyprus and Malta are thoroughly surveyed. The other islands scattered throughout the ocean which fly the Union Jack, including the West Indies, while their coast lines have naturally been the subject of close attention by the Hydrographic Department of the Admiralty, are, as regards their internal geographical features, still quite imperfectly known. The large and important territory of British Guiana is entirely unsurveyed, and indeed in part almost unexplored.

You will thus realise that if we are prepared to admit the validity of the premiss that the mapping of its own territory is an imperative duty of a State which aspires to justify itself before the nations as the possessor of a world-wide Empire, there is still plenty of employment for the scientific geographer in the British dominions.

Having thus far spoken of our duties and obligations, for such they appear to me, which lie abroad in countries remote from our own shores, let us now turn our eyes inward and see if we cannot discern some similar duties lying close to our hands.

I take it that the great majority of us have been brought up in the idea that our own Ordnance Survey is of such a high order of accuracy that a proposal to undertake a revision of the fundamental triangulation of the British Isles must appear strange. Yet this idea will not be a new one to the British Association, for two years ago at the York meeting I brought the subject before this Section in a short note, which gave rise to a useful discussion.

What I shall say now will be in a large measure a repetition of my previous remarks, a repetition for which I need offer no apology, as it will be apparent to you that had any steps been taken to remove this standing reproach to British geodetical science no recurrence to the subject would be called for. As matters stand, however, I feel impelled to recur to it with increased emphasis, a position in which I am confident of being supported by all those who earnestly care for the scientific repute of our country. Some few years ago, at the request of the International Geodetic Conference, a volume was prepared by General Ferrero, the eminent Italian geodesist, giving a summarised account of all the geodetic surveys of the world. If we take this volume and examine the relative degree of precision of the different national surveys there enumerated we shall find that Great Britain stands lowest on the list.

The popular illusion, for it is really no other, as to the extreme accuracy of the triangulation of the British Isles rests in no small degree upon what must be considered a fortuitous circumstance—namely, the accidental smallness of the closing error. Have we not all been told how at the conclusion of the triangulation, when the observations had been carried from the primary base on the shore of Loch Foyle across part of Ireland and across Wales and England, terminating in two points on Salisbury Plain, the distance between these points was calculated, using as data the measured length of the Loch Foyle base and the observed angles of the triangles across the country? The distance between the same two points was then measured with every refinement of accuracy, and the measured length compared with the calculated length. The difference between them was found to be twenty inches. If in traversing a large portion of the kingdom the aggregate error only amounted to this minute quantity—minute, that is, compared with the distances involved, how can we either expect or demand a better result, even if the work be redone with the most refined methods that the accumulated experience of the last fifty years can suggest?

To answer this question we must bear in mind that the closing error of a piece of work such as a triangulation is not the only, nor indeed the best, test of its precision. A small closing error may be due to accident; larger discrepancies may have occurred at intermediate stages which have chanced nearly to cancel themselves at the end. Such undoubtedly did happen in this case. The work was not as accurate as the smallness of the closing error would seem at first sight to imply. We have, however, in such a case an absolute measure of relative precision in the magnitude of the average triangular error, being the quantity by which the sum of the observed angles of a triangle exceeds or falls short of the true value of 180° + spherical excess.

From this we can readily deduce the 'probable error' of a single observed angle, a form in which the measure of precision of a triangulation is often expressed.

In our British survey this quantity equals 1·20 second of arc, while in good modern work it does not in general exceed 0·25 second. Making due allowance for the fact that the network of triangles over our islands is a complicated one, and therefore that the ultimate precision is considerably greater than that of a chain of triangles of the same order of individual accuracy, we are probably justified in concluding that a resurvey would at least halve the final errors.

Such a resurvey is urgently demanded in the interests of international geodesy.

It will of course be clearly understood that this implies no adverse criticism upon the work of the men who originated and carried out the primary triangulation of the British Isles. For that great achievement we must all have the most sincere admiration. It was pioneer work of the highest order; it set a standard of accuracy never before attained, and was for long taken as the model for such work in other countries. It was, however, started at the end of the eighteenth century and was completed in 1857. It is therefore hardly surprising that it falls somewhat short of the precision of modern observations of the same class. It will also be understood that this resurvey does not affect the question of the reliability of our Ordnance Survey maps. Any errors which exist in our triangulations are important only for geodetic discussions, such as the determination of the exact figure of the earth, and are quite negligible for map-making purposes. There can be no appreciable error from this cause upon the maps of our own country, even those on the largest scales, and no question of reconstructing our maps can arise. This is fortunate from the financial point of view. Such a reconstruction would involve a very heavy expenditure, while the cost of the retriangulation suggested would be quite trifling compared with the actual annual expense of our national surveys.

The result of this inferiority in accuracy of the British survey is that it is useless to co-ordinate it with the continental series for geodetical purposes. This defect is all the more noticeable in that the necessary observations for joining up the two series were actually made. Three stations on the coast of Kent—St. Peter's Church, between Margate and Ramsgate; Coldham, a hill about two miles north of Folkestone; and Fairlight, a hill about four miles north-east of Hastings—were connected trigonometrically with three stations in France—Montlambert, near Boulogne; St. Inglevert, over the village of Wissant; and the Clock Tower at Gravelines. This was done in 1861–63. The observations were of a high order of precision. It would not be necessary to repeat them.

The importance of the co-ordination is apparent when we inspect a map of Europe with the neighbouring part of Africa, upon which the triangulation lines are entered. We then see that the British part of the work is imperatively required to extend, and in fact to complete at one end in each case, two important geodetic arcs, viz., the meridional arc along the meridian of Greenwich and the longitudinal arc along the latitude of 52° north. Without the British portions these arcs extend from Ain Sefra in Algeria to Gravelines in France, an amplitude of 18°, and from Orsk in Russia to the same point in France, an amplitude of 57°. With the British section added they would be further extended to Saxavord, the northernmost point of the Shetland Islands, and to Valentia, on the West of Ireland, respectively. The added amplitudes would be 10° and 11½°, very material additions, which would undoubtedly prove of substantial scientific value.

It will thus be seen that it is by no means necessary, or even desirable, to re-observe the whole network of triangles covering our islands. All that is required is to connect geodetically the three extreme points—Saxavord, Valentia, and the stations on the Kent coast just mentioned.

A knowledge of the exact figure of the earth is of high scientific importance, especially so in reference to recent speculations as to its possible deviation from a spheroidal form. It cannot be other than a subject of national shame that so important a link in this research remains unfilled. We may note with gratification the forward position that our nation has in the past taken in the advancement of geodesy. We know the great work done in the triangulation of India, and we have alluded to the magnificent conception of the Cape to North Sea arc due to Sir David Gill. Surely it is not asking too much that we should take steps to set our own house in order, and to ensure that our own triangulation is at least as accurate as that covering the neighbouring portions of the continent of Europe. The subject is one upon which the powerful influence of the British Association might legitimately be brought to bear, and any representations from our body would come with a peculiar appropriateness from this the Dublin meeting, seeing that so large a section of the work, whose importance we wish to urge upon the Government, lies upon Irish soil, whose execution would therefore devolve naturally on the Ordnance Survey of Ireland.

In concluding this Address I feel constrained to apologise for what may have appeared to some of you the dull and unromantic character of my theme. I am too well aware that to many the idea of geographical advance is confined to the perilous traversing of virgin lands, to the navigation of unknown waters, and to the penetration of forests or deserts never yet trod by white men's feet. I am conscious that the substitution of the surveyor for the explorer has necessarily destroyed much of the old romance, and that the feelings born when any fraction of the earth's surface was for the first time opened to our ken can never be revived. While, however, the romance has gone the dangers remain, and there is as much call now for unflinching courage and for unselfish devotion to duty as there was in the days when the search for the sources of the Nile was an impelling cause sending adventurous men into the unknown. Whether occupied in cutting his way through the almost impenetrable forests of the Gold Coast or struggling with the papyrus swamps of the Nile basin, or whether, standing upon the top of some old volcanic hill, he is engaged in scanning the blue distances of the great Rift valley, the surveyor is not less worthy of your admiration than the earlier traveller whose name is perhaps honourably enshrined in that of river or mountain. Whether pushing his way through the jungles of the Malays or floating upon the muddy stream of an African river, whether he is braving the attacks of savage animals, of treacherous natives, or the far more insidious assaults of the germs of some deadly disease, he is equally deserving of your sympathy and your encouragement. He is in truth a shining example of the power of that spirit of adventure and thirst for information which has carried our race so far in the past, and which in the future is, we all trust, destined to lead us ever 'upwards and on'; the spirit that esteems no sacrifice too great in the cause of duty, and recognises no duty so high as that of making some contribution towards the increase of natural knowledge.

The following Papers were then read:—

1. *The Physiographic Subdivisions of the Appalachian Mountain System, and their Effects upon Settlement and History. By* Professor W. M. Davis.

The Appalachian mountain system of the eastern United States may be divided into two longitudinal belts—the crystalline Appalachians on the south-east, and the stratified Appalachians on the north-west; with these may be associated the Appalachian plateau, of horizontal structure, next further north-west. Each belt varies somewhat when followed along its length. The crystalline belt is low, narrow, and interrupted in a middle section; it is higher and broader in the north-east and in the south-west. The stratified belt is most characteristically developed in a middle section, where alternations of resistant and weak strata result in alternations of ridges and valleys; in the north-east the ridge-making strata are absent; in the south-west they are of less strength than in the middle section. The plateau belt continues in full strength along the greater part of the stratified belt in the United States, but it terminates in eastern New York; further north it may be said to be replaced by the Adirondack Mountains, separated from the plateau by the Mohawk Valley. The relation of these various features to geological structures and to processes of erosion, and their effects upon settlement and history, were briefly sketched in this paper.

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2. *Ireland: her Coasts and Rivers.*
By Rev. W. Spottswood Green, *C.B.*

The more intimately we know a country the greater is the interest in investigating its condition in the ages long gone by, and tracing the connection between the past and the present. This is true, whether we look on the question from a geographical or from an historical point of view. The present has been evolved out of the past, and geographical and social conditions are so bound together that they may almost be looked at as aspects of the one problem. To make this clear it is only necessary to take an imaginary illustration. If, for instance, the geography of the British Islands could be so altered that Ireland lay to the east of England instead of to the west of it, how profoundly would her history have been affected!

It is impossible, in the brief space available, to follow up the geographical history of the past. All I can hope to do is to touch on some salient points, and, with some photographic illustrations of the coasts and rivers of Ireland, treat the succession of events from the time that the river valleys were being sculptured and the present configuration of the country determined through the great Arctic and Forest periods to the coming of man into the island, the evolution and admixture of races, and the scenes of beauty which we hope that many who come to the British Association may go on and see for themselves. It is impossible, also for lack of time, to name all the authorities upon whose writings my outline sketch may be based; but it is well to notice that as all writers of note have now adopted the modern historical methods, and place truth before sentiment, the conclusions arrived at about Ireland's past are based on as wide an induction as the materials for European history permit.

FRIDAY, SEPTEMBER 4.

The following Papers were read:—

1. *School Geography as a Mental Discipline.* *By* Professor R. A. Gregory.

No teaching of science in schools is satisfactory unless the scientific method of study is followed. There are many science subjects, but only one scientific method; and it consists in the collection and arrangement of facts—obtained so far as possible by personal observation and experience—with the view of discovering relationships and arriving at correct conclusions. A literary subject taught in this spirit is of greater educational value than a science subject in which the instruction is chiefly of a didactic character. What is most important is not the subject, but the method, of study.

In the modern teaching of physics, chemistry, nature-study, and similar subjects in schools, the aim is not so much to accumulate a large amount of information—useful or otherwise—as to create and foster an active and independent habit of mind; individual contact with facts, and the critical study of evidence, are thus encouraged instead of the passive absorption of statements made by a teacher or a text-book.

By the introduction of practical exercises both in school and out, geography is being brought into line with other subjects taught by truly educational methods. It is being recognised slowly that the scientific aspects of geography should be matters of personal observation rather than of description. Nothing should be told a pupil which he can find out for himself by suitable exercises. The construction of a plan from actual measurements gives a knowledge of scales; and with this mental equipment the transition is easy to a simple map of the district, upon which exercises can be set. When such a map is understood, work may be done upon maps of the British Isles, either physical, political, or showing roads and other ways of communication. After the natural physical divisions of our islands have been studied by exercises based upon orographical maps, the characteristics of British climate may be investigated. For this purpose familiarity with meteorological instruments is necessary.

It is an educational axiom that no numbers or other symbols should be used until their meanings are understood. No study should be made, therefore, of records of temperature, rainfall, or other meteorological phenomena unless the numbers convey definite ideas to the pupils. In all cases pupils should be encouraged to arrive at a principle or generalisation from the material put before them, whether in the form of results of observation or of maps. It will then be understood that every point upon a map represents results of investigation, and that every geographical generalisation has been obtained by the study of facts recorded by various explorers and observers. This method of approach may be extended to the whole world at any convenient stage of the course, the intention throughout being to use geographical material to stimulate intelligent inquiry, and be a means of mental discipline, rather than as information to be remembered merely. The practical exercises in the class-room as well as in the field should thus be regarded as illustrations of the methods by which geographical science has been built up, and to provide a vocabulary by means of which geographical facts may be interpreted.

It must not be supposed that the neglect of the human and imaginative side of geography is suggested; all that is here advocated is that whenever possible pupils should be brought face to face with evidence and trained to study it. The best way to obtain evidence is by direct observation; but as it is not practicable for a single investigator to compass the world by personal inquiry, the results of observations made by others may be used as material to be sorted, grouped, compared, and generalised, provided that its nature is understood. Combined with this collection and consideration of concrete facts there should be a course of reading or descriptive lessons intended to inspire interest in the earth and its inhabitants, and to cultivate appreciation of what may be termed the intangible influences and factors of geographical character. Taught in this way, geography may be made one of the most valuable subjects in a school curriculum, for it provides not only the intellectual discipline of a science rightly studied, but also the human interest and sympathy of the most inspiring literature.

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2. *The Geographical Study of Mediterranean Man, considered as an Element in a 'Classical Education.' By* Professor JOHN L. MYRES, *M.A.*

Some years' experience in teaching classical subjects, and particularly ancient history, to university students, mainly derived from the principal public schools, shows that one of the principal defects in the equipment which these students bring is that both their special historical knowledge and their general conception of the social life and surroundings of the Greek and Roman world have been formed without regard for the geographical conditions in which Mediterranean societies were formed and developed. Geography in the public schools seems to be taught (when it is taught at all) as an isolated discipline, without regard to its application in any particular department of human history. Yet in this instance a school with a classical curriculum cannot plead the impossibility of correlating the geographical lesson with varying regions of historical study. For in a classical curriculum the historical studies all have as their subject the doings of one section or other of Mediterranean Man, and the region which he inhabits forms as well-defined and manageable a subject of geographical study as could easily be devised. Experiments which have been tried, both at universities and in public schools, suggest that the introduction of a systematic study of the Mediterranean region on broad geographical lines at an early stage in the classical course has at the same time the effect of familiarising the students with the main principles of geographical inquiry, and of presenting to them, in an impressive, methodical, and yet a most natural way, the outlines of the history and the social life of the peoples whose language, literature, and beliefs are to be their principal study. Correlation of studies, in fact, is here particularly easy to secure.

In the present stage of development of the schools in question the only serious difficulty is the lack of teachers of classics who have undergone any systematic geography training at all. The remedy, therefore, would seem to be *first* to insist at the universities on the acquisition, during the normal university course, of a far higher quality of geographical knowledge than is at present presumed; for example, in the Final Classical School at Oxford, or in the Classical Tripos at Cambridge. The existence both at Oxford and at Cambridge of an organised staff for the teaching of pure and applied geography would make this change quite easy, if the tutors and examiners could once be brought to see its practical utility. *Secondly*, when once the universities have been persuaded to insist upon a higher minimum of geographical knowledge than at present from their classical studies, it will be possible for headmasters to require from candidates for assistantships a knowledge of classical—that is, Mediterranean—geography, which at present they do not appear to want, and could not secure if they did.

Meanwhile those few schools which have succeeded in securing either a classical master with geographical interests, or even a geography master who understands the special needs of classical students, are the best illustrations of the vividness and coherence which can be put into the classical curriculum by insistence on a geographical point of view in dealing with Greek and Roman civilisation.

At present there is the familiar deadlock: headmasters who set store by academic distinctions have no use for boys with geographical knowledge, and consequently no use for geographically minded teachers; the universities, hearing no cry for geographically minded teachers, have no inducement to offer academic distinctions to students with geographical knowledge.

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3. *Scientific Results of the Voyage of the 'Scotia.'* *By* William S. Bruce, *LL.D.*, *F.R.S.E.*

The 'Scotia' was specially fitted out for oceanographical and meteorological research in high southern latitudes.

Magnetism.—No magnetic research was done on board the 'Scotia,' since this was not compatible with deep-sea trawling, sounding, &c., but at Scotia Bay, South Orkneys, a magnetic observatory, named Copeland Observatory, after the late Professor Ralph Copeland, was set up, when Mr. R. C. Mossmann carried out a series of magnetic observations during the wintering of the 'Scotia,' and during her absence coaling and refitting at Buenos Aires for the second voyage.

Tides.—Tidal observations were made, under the direction of Captain Thomas Robertson, every half hour at Scotia Bay. These are of special interest as being a record in the most open stretch of ocean in the world. Their normality is their striking characteristic.

Meteorology.—Observations were taken by and under the direct supervision of Mr. R. C. Mossman. The results are especially important, since the Argentine

Republic agreed to continue the Scotia Bay observatories and have now secured five years' continuous records there. One of the most important results of these records is that they seem to indicate an extensive continental land mass not far to the south and west of the South Orkneys. This is specially emphasised by the observations at Scotia Bay, off Coats Land, and near the position where Morrell reported land and Ross an 'appearance of land.' The observations show that the line between the easterly and westerly systems of weather is in about 65° S. in the Weddell and Biscoe seas; the South Orkneys being well within the westerly system.

Ocean Physics.—The large series of observations are only now being worked up, but they must give us a large amount of new and important information.

Deep Sea Deposits.—The deep-sea deposits indicate by the continuous band of terrigenous deposits between 65° and 74° S. a corresponding extensive continental coast-line to the south. The characteristic blue muds, as well as the great rock-masses, strongly continental in character, give ample proof of an extensive land mass to the south.

Bathymetry.—The results of the extensive sounding operations change our ideas of the bathymetry of the South Atlantic Ocean, the Weddell Sea, and the Biscoe Sea. The Ross Deep has been obliterated, and relatively shallow instead of very deep water was found to extend to the northward. Actually in the portion where Ross reported 4,000 fathoms, no bottom, Bruce reached bottom in 2,660 fathoms, and brought up a sample of blue mud. Connecting rises of less than 2,000 join Graham's Land, South Orkneys, and the Sandwich Group, as well as the south of South America and Antarctica. South of Gough Island, where the 'Scotia' naturalists made interesting ornithological collections, Dr. Bruce sounded out a continuance of the mid-Atlantic rise a thousand miles to the south, and this rise probably joins another rise between the Sandwich Group and Bowet Island, which rise continues north-eastward to meet Madagascar and the east coast of Africa. The deep lying to the east of Argentina, therefore, seems to be separate from that of the Biscoe Sea, and both these are separate from the deep lying to the south-west of South Africa. The shelving of the water in the south and west of the area bathymetrically surveyed by the 'Scotia' in the Weddell Sea also gives additional weight to the hypothesis of an extensive and continuous land mass existing between Kemp, Enderby, Coats, Morrell, and Moss's supposed land and Graham's Land.

Topography.—The Scottish Expedition surveyed Laurie Island, South Orkneys, on a scale of two inches to the mile. They included in this survey local hydrographical work. A running coast survey was also made of the north side of Coronation Island, as well as of 150 miles of the new coast-line which the expedition discovered and Dr. Bruce named Coats Land in honour of the two chief supporters of the Scottish National Antarctic Expedition.

Biology.—Besides making surface and shallow water collections, the Scottish naturalists trawled in great depths, not only south of 40° S., but also south of the Antarctic Circle, many trawlings being in water exceeding 2,500 fathoms. Bipolarity fades away, for not only do North and South Polar species differ widely, but even species from different South Polar areas. The northern extension of Antarctica at Graham's Land appears to be a potent factor in this matter.

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4. *The Northward Expansion of Canada.*[1] *By* W. L. Grant.

At its formation, in 1867, Canada extended from the Atlantic to Lake Superior; by the purchase of its rights from the Hudson's Bay Company in 1869, and by union with British Columbia in 1871, it reached the Pacific. But a country is really measured, not in square miles, but in the area which men can inhabit and develop. At federation the inhabited country was but a thin and broken strip along the American frontier. Wildernesses separated the maritime provinces

[1] Introductory to the visit of the Association to Canada in 1909.

from Quebec, and Ontario from the West; from Winnipeg to the Rocky Mountains was the home of a few Indians; three ranges of mountains shut in British Columbia. North of the 'Height of Land' in Ontario and Quebec all was wilderness. Canada was length without breadth, and even the length was not continuous.

The progress of the country has consisted not so much in any change of climate or of geographic conditions as in (1) the spread of knowledge as to what the conditions really are; (2) with the growth of knowledge the growth of popular confidence; (3) the conquering of such conditions as were unfavourable. Man is to-day the ruler, not the slave, of geographic conditions. He is no longer forced to follow the rivers; settlement no longer creeps from point to point. The railway goes hundreds of miles in advance of settlement, and everywhere finds land where men may live and prosper. The new transcontinental railways pass through the province of Alberta more than 300 miles north of the American frontier, and already settlement has extended north of the railways. In Ontario and Quebec, north of the Height of Land, great tracts are being opened up by new railways, and are being found rich not only in minerals and in timber, but also in arable land. A study of railways is to-day more important than a study of rivers.

With this widening of habitable territory goes an increase in political and economic unity; that which was at first only a paper federation is being welded together.

At the heart of this network of railways lies Winnipeg, the central city of Canada. The railway map of Canada is in shape not unlike a wasp, with its waist at Winnipeg. Perhaps the greatest danger to which Canada is exposed is that the waist may be too small. A railway running north of Lake Winnipeg should be one of the next links forged in the building together of Canada.

MONDAY, SEPTEMBER 7.

The following Papers were read:—

1. *New Instruments for Travellers and Surveyors.* *By* E. A. Reeves, *F.R.A.S.*

This paper gave a brief description of three instruments recently designed by the author for the use of travellers and surveyors:—

1. *The Distance-finder Alidade for Plane Tabling.*—This consists of an aluminium ruler $2\frac{1}{2}$ feet long, at each end of which is fitted a small telescope placed at right angles to the ruler. One telescope has a vertical and horizontal wire only fitted in the diaphragm, while the other, in addition to these, has a movable micrometer wire and drum. In taking a distance the plane-table with the alidade is levelled, and then the telescope with the simple cross wire only is sighted on to a definite point of an object of which the distance is required, after which the surveyor passes to the other telescope, and, covering the same point of the object with the movable micrometer wire, reads off the divisions recorded on the micrometer. To eliminate errors in parallelism, the measurement is repeated with the alidade and telescopes reversed, and the mean of the divisions noted. With this mean a scale on the alidade ruler is entered and the corresponding distance in feet read off. A $2\frac{1}{2}$-foot instrument will give direct distance up to about 1,000 feet with fair accuracy; by repeating the observations and with the distance so obtained, by a simple system of similar triangles, distances eight or ten times as far can be measured without altering the position of the plane-table. The whole operation is very rapid, and the great advantage of the instrument is that it enables a surveyor to fill in a considerable amount of detail without moving his board, and that he can obtain distances to points which he may be unable to reach. The telescopes can be taken off the ruler, and one of them is

fitted with a small circular arc and can be placed in a line with the ruler, when the instrument can be used as an ordinary telescopic plane-table alidade. Larger sizes of the distance-finder, with longer rods, are made fitted to a stand as a separate instrument, and the instrument can be combined with a theodolite for traversing.

2. *The Astronomical Compass and Time Indicator.*—This is a simple and inexpensive little instrument for quickly finding the north and south line and the true bearing of any object, as well as the local mean time by the sun or stars with sufficient accuracy for all ordinary purposes. It has been designed by me to meet the requirements of travellers and for night-marching when the ordinary magnetic compass cannot be relied on.

The instrument consists of two small discs, upon each of which is a projection of a hemisphere drawn on the plane of the meridian. One of the discs shows, in black, parallels of declination of the principal stars and of the sun at different dates, with hour circles subdivided into five minutes, while the other, the upper one, is transparent and shows, in red, curves of altitude and azimuth. The two discs are centered on a pivot, and the transparent one is weighted at the lower part to keep it vertical. Through the central pivot passes a pin, carrying a sight-rule or alidade on the front of the transparent disc and fixed to the handle at the back.

When the instrument is used as a *compass* the N. or S. pole of the declination circle is first set to the red number on the transparent disc equal to the latitude of the place; then, allowing the discs to swing freely, clamped together, a rough altitude of the sun is taken through the sight-rule. The altitude circle indicated by the pointer at one end of the sight-rule is now followed across the disc until it intersects the curve of declination of the sun or star observed, seen through the transparent disc, and the red longitudinal curve passing through the point of intersection gives the true bearing or azimuth of the star or sun at the time. Then, considering the upper disc as a compass card with the zenith as the true N. point, the sight-rule is set to this bearing, counting the degrees round the circumference of the disc. Now when the discs are held horizontal with the sight-rule aligned on the sun or star observed, the true north will be indicated by the large red arrow on the transparent disc. There is an additional movable pointer which can be previously set to any bearing upon which it is desired to march. The lines are all bold, so that they can be read off easily at night. The whole operation is extremely rapid, so that bearings at intervals of a quarter of an hour or so can be taken without delay.

The same observation that gives the true bearing also furnishes *the time*, since the hours and minutes read off the black figures of the declination disc at the point of intersection indicate the hour angle of the sun or star. This hour angle, of course, in the case of the sun gives the local apparent time, which can be converted into mean time by applying the equation of time taken from the table at the back, where a diagram is also given from which the approximate local mean time can be quickly found without any computation from the hour angle taken off as in the case of the sun.

3. The third instrument to which attention was called is a new form of reflecting *artificial horizon.* It is intended for land or sea use, and it is hoped will be of service in Polar exploration on moving ice. The special advantages claimed for it over other attempts at the same kind of instrument are (1) that by the system of taking observations errors are counterbalanced and a good mean obtained; (2) that it can be readily fitted on in front of a sextant when required for use, and afterwards taken off; (3) that no arrangement is required for illuminating wires for star work. Meridian altitude latitudes on land have been frequently taken with this artificial horizon to within 8″ or 10″ of the truth, and on sea the results should be near enough to be quite useful.

This artificial horizon is very simple in construction, consisting merely of a reflecting mirror kept horizontal by a short weighted pendulum, of which the weight is slightly below the centre of gravity. The mirror is adjusted to move accurately in the plane of the index and horizon glasses of the sextant by means of adjusting screws, and altitudes are taken in pairs, the artificial horizon being reversed laterally between each observation and the mean result accepted. This is a special feature in connection with the instrument, and to a great extent eliminates errors.

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2. *Notes on the Cartography of the Counties of England and Wales. By* HERBERT GEORGE FORDHAM.

This paper summarised the results of the author's inquiries into the history, bibliography, and geographical characteristics of the engraved maps of the English and Welsh counties. From the survey of Christopher Saxton, and the publication of his atlas of thirty-four maps in 1579, to the present day there has been a remarkably complete sequence of such maps, which will repay a careful study, both from the point of view of the science of cartography and of that of the artistic side of topographical representation. The author, in examining exhaustively the cartography of two English counties (Hertfordshire and Cambridgeshire), has established the chronology and characteristics of the maps of the whole period here reviewed, and has followed up in detail the history of the publishers, engravers, and topographical writers of the three centuries in their connection with British cartography generally. He indicated the position of the Dutch, Flemish, and French schools of geographers in relation to the contemporaneous work in England at different periods, and established a classification by reference to the initial meridian lines adopted, and to the style and art developed by engravers in this department. He also noticed the principal authors and their best-known works in chronological order, and mentioned, by way of illustration, that in all nearly 400 maps have been published of the county of Hertford, of which, however, more than one-half are reprints, more or less altered from the original plates, and may be regarded as duplicates. Any complete collection of the whole series of engraved maps of a county in England or Wales, 1579–1900, would contain approximately the same number. The object of the communication was to draw attention to the large and almost unworked field of research which exists in connection with the bibliography and classification of maps from the early period of their production by the engraver's art.

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3. *The Longitudinal Section of the River Nile. By* Captain H. G. LYONS, *R.E., F.R.S.*

The increase of cultivation in Egypt during the summer months has necessitated an increased supply of water during the low stage of the river, and at this season of the year the equatorial lakes, and that portion of the Nile system which flows from them, alone can furnish it. The Abyssinian tributaries—the Sobat, the Blue Nile, and the Atbara—are in these months discharging little or nothing. As soon, therefore, as the Dervish power had been broken the survey of the Upper Nile was commenced. During the past eight years much has been done, and, among other results, an almost complete line of levelling now exists from the

Mediterranean to Lake Victoria, a distance of 3,500 miles. This newly acquired information enables us to discuss the longitudinal section of the Nile more completely than has hitherto been possible. A discussion of the material now available shows that the probable discrepancy where the two portions of the line join is not greater than about 25 or 30 feet.

The section shows clearly the great crustal blocks of which the equatorial plateau is composed, while the lakes occupy the level surfaces of the blocks—as Lake Victoria, Lake Choga, Lake Albert Edward, and Lake Albert. This portion of the basin exhibits the characteristic features of recent development. At the foot of the equatorial plateau the level plains of the Sudan commence. Through these the rivers of the region drain—viz., the Bahr el Jebel, the Bahr el Zaraf, and others—but now their slope is known not to be very low, being about 1 in 20,000, or a little more than three inches to one mile. The great development of marshes in this region is not so much due to the flatness of the plains, but to the water-level being so near to that of the flood plains that vegetation grows luxuriantly throughout the year, and all the river silt is arrested in the upper reach, so that the flood plains are not being built up.

Between the Sobat River and Khartoum is the flattest portion of the whole course of the river; the slope varies from one-half to one-third of an inch per mile, and when the Blue Nile is in flood the White Nile is ponded up and presents an absolutely horizontal surface for 300 miles.

Below Khartoum the character of the river-bed changes; reaches of rapids where the river is eroding the crystalline rocks alternate with reaches of lower slope where the rock is sandstone. These crystalline rocks therefore form natural obstructions which can easily be converted into dams for storing up water in the valley above. When the question of increasing the volume of water stored in the reservoir at Aswan was under consideration, three of these reaches were contoured carefully to determine what volume of water could be stored in them.

In these rapids the slope is at times steep, but never for any considerable distance, and the mean inclination rarely exceeds 1 in 1,000 for any length of river. At no point can the river be said to descend a vertical fall, as the term cataract might be thought to imply; but the cataracts of the Nile are in fact reaches of the river in which it has cut its way down to portions of the ancient and uneven land-surface formed of the crystalline rocks on which the sandstones of Cretaceous age have been laid down. The position of the ridges of this ancient land have determined the places where cataracts occur, but the water-channels in them follow the lines of weakness due to bands of softer rock or to lines of fracture caused by the movement of the crust during long ages. The last of these barriers is at Aswan, and below this the river flows in the wide alluvial plains which it has formed by deposition, and which it is building up at the average rate of about four inches per century. The equatorial plateau and the region of the cataracts are regions in which the river is eroding at the present time, while in the Sudan plains and in Egypt deposition is taking place. But little accurate levelling has as yet taken place along the Abyssinian tributaries, and from Khartoum to Fazogli along the Blue Nile only are the levels reliable. Here in one reach near Singa the slope is markedly less than either upstream or downstream of it, and this may be due to a warping of the crust at this part; but more evidence is needed.

TUESDAY, SEPTEMBER 8.

The following Papers and Reports were read:—

1. *A Journey into the Primeval Forests of Tropical Peru.* *By* L. C. Bernacchi.

This paper dealt mainly with the region of the Rio Inambari, which the author visited, and where a preliminary survey was carried out in 1907, at the expense of an English rubber company, in a district practically unexplored. The author started from Santa Rosa, on the Peruvian Corporation railway. On the steep eastern slope of the Andes a notable variety in succession of temperature, scenery, and vegetation was observed, as were remains of a former population. The present population is mainly Quichua, with whom the Atsahuaca, of whom there are few, strongly contrast in their excellent nature and disposition. The Atsahuaca are nomad hunters and monogamists, and are nearly extinct in the Inambari valley. The author quoted at some length from the survey report; the work carried out is the most complete survey yet made of this part of the continent. Rubber and trading companies are gradually opening up the country. The forests of the Inambari abound in fine Para rubber-trees of the Hevea variety.

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2. *Unique Experiences at the Birth of a Volcano.* *By* Rev. George Furlong.

The author witnessed, in August 1905, the birth and development of the volcano, now called O Le Mauga Mu, in Savaii, which island exhibits lava-fields in almost every stage of formation. After a period of earth unrest, two fissures opened on August 4, flame-coloured steam and vapour broke forth with heavy explosions, and masses of débris were ejected which soon began to build up the crater. Streams of lava carrying other matter rolled from the vent; their rate of progress was calculated at half a mile in twenty-four hours. The behaviour of these lava-streams was watched and described in detail by the author. He points out (among other phenomena) that the surface of the lava quickly solidified, and thus a tunnel was formed through which the flow went on, so that between the crater and the vast columns of steam where the lava reached the sea it was difficult to realise that volcanic action was in progress. It was noted that the volcano was more active during the period of full moon than of waning moon; also that the fumes from the volcano were not always of the same nature. Several tidal waves were experienced, always in the same place; they were about 500 yards wide, and flowed inland from 100 to 120 yards. These waves were observed to occur when the crater was more than usually active.

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3. *Report on the Exploration of Prince Charles Foreland, Spitsbergen.*

See Reports, p. 306.

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4. *The Marble Arch Caves in Co. Fermanagh.*[1] *By* Harold Brodrick, *M.A.*

Three streams flow down the northern slope of Cuilcagh and sink into the limestone at three points about a quarter of a mile apart; the central stream goes by the name of the Monastir. The narrow limestone valley through which it runs is cut off, at its lower end, by a limestone cliff 130 feet high. The cave at the base of this has a total length of 40 yards, and ends in a fissure of unknown height. Within 40 yards of the top of the cliff is a pot-hole (Pollbwee) 100 feet deep, with a pool and a narrow passage 60 feet in length at the bottom. Further north is an opening in the moor called Pollnagapple; this is a pot-hole with a diameter of 80 feet and a depth of 60 feet. Its floor is composed of jambed boulders, below which the river can be heard; a high cave with good stalactitic deposits leads from the bottom of this pot. About 150 yards further north is Cradle Hole—a pot-hole 80 yards in diameter and 120 feet deep; at the base are two caves in which the stream is met with; upstream the passage, 15 feet wide

[1] A full account of these caves, with plans, will be published in the *Irish Naturalist.*

and 25 feet high, has been explored for 55 yards, but has not been surveyed. The downstream cave is from 10 to 25 feet high and 30 feet wide; it is 104 yards long and ends in a pool within about 20 feet of the upper end of Marble Arch Cave. The roof seems too low to admit of passage. The Marble Arch Cave is entered from lower down the hillside. At the upper end of the stream course is a pool, probably the continuation of the one met with in Cradle Hole. The stream flows for 123 yards along the 'Grand Gallery,' through boulders and shingle, to the 'Junction.' The 'Grand Gallery' is from 5 to 20 feet high and about 15 feet wide. At the Junction the roof is at least 50 feet high; from here the stream turns to the left and then to the right, filling the whole of the passage; it here forms a lake at least 10 feet deep in the centre. At 84 yards from the Junction a beach is reached and 10 yards further the open air, at the floor of a wide pot-hole 60 feet deep; from this beach the stream flows under low arches to another lake, from which it emerges into the open just above the Marble Arch itself. A high-level passage leads from above the beach to the shore of this lake, and a second branch leads through boulders to the open at the bottom of a wide pot-hole 30 feet deep, in the floor of which is also another opening, which will be referred to later.

From the Junction a dry passage runs to the right, and at a distance of 45 yards becomes 20 yards wide and about 40 feet high; the floor rises to the left, but the passage continues forward to the right. To the left the rising floor is composed of boulders and sand cemented together and covered with stalagmite. At the upper end of the slope is a fine collection of stalactites. A low passage 15 feet wide leads from here into a fissure cave 30 feet high and 50 feet long. The low-level passage at the bottom of the boulder slope continues for 93 yards, 15 to 25 feet in height and about 10 feet in width, to the 'Pool Chamber.' This is about 15 yards in diameter and 20 feet high, and has a still pool at its lowest point. Beyond this chamber the passage continues 15 feet wide and about 4 feet high, and in 12 yards is blocked with boulders. A climb of about 15 feet vertically upwards through these boulders leads into the bottom of a chamber about 80 feet high and 25 yards in diameter, the floor of which is entirely composed of a slope of large boulders. The upper end of the boulder slope leads to the bottom of a narrow pot-hole 30 feet deep, for the descent of which ladders are necessary. At the far corner of this chamber there is a small hole leading, between jambed boulders, into the floor of the pot-hole into which the high-level passage opens, and within 20 feet of the end of the passage. The portion of the cave beyond the Pool Chamber and the two openings there were unknown before this year. Fluorescine put into the Monastir Sink at 11.30 A.M. in dry weather was clearly visible at Cradle Hole at 10.45 A.M. the following day, and at 6.45 the same evening began to emerge at the Marble Arch spring.

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5. *Mitchelstown Cave.* *By* Dr. C. A. Hill, *M.A., M.B.*

Mitchelstown Cave, the largest yet discovered in the British Isles, is situated in co. Tipperary, in the valley of the Blackwater. There are actually two separate and distinct caves. The existence of one, the 'old' cave, is now forgotten, though this cave was known and exhibited in 1777. The 'new' cave, first discovered in 1833, is now the only one shown to visitors. It was first described by Dr. Apjohn of Dublin, who partially explored and surveyed it in 1834, and published a map which has been the basis of all others up to the present time. It was further explored by M. Martel of Paris in 1895 and described by him, and was also visited by Dr. Lyster Jameson of Dublin, who described the cave fauna found therein. Very little is known of the full extent of the caves even at the present day, and no reliable plan or map exists. The cave was visited in 1905 by the author, who took many photographs now shown for the first time, and also explored portions hitherto unvisited. The cave was found to be of much greater extent and complexity than was previously imagined.

There is great need for systematic exploration and surveying, as the existing plan of the 'new' cave has been found inaccurate and misleading, and practically nothing is known of the 'old' cave. Geologically the 'new' cave is of great antiquity, as evinced by the enormous size and number of the stalactite and stalagmite formations. There is no evidence of present active water-action, the cave being practically dry, except at two points erroneously called 'the River.' The explored passages are estimated at a mile and a quarter in length.

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6. *Third Report on Investigations in the Indian Ocean.* See Reports, p. 305.

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7. *Report on the Oscillations of the Level of the Land in the Mediterranean Basin.*—See Reports, p. 308.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section.—W. M. Acworth, M.A.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address:—

The Relation of Railways to the State.

No one can be more conscious than your President of to-day of the unfitness of one who has no claim to be called an economist at all to occupy the Chair of this Section in succession to a long line of the most distinguished economists of the country. But it would be affectation on my part to ignore that I owe the distinction, however little personally I may deserve it, to the fact that what our American friends call transportation problems are much to the fore at present, and that to those problems the professed economists of this country have unfortunately —for reasons that there is no need to discuss here—hitherto devoted but scant attention. And *parmi les aveugles le borgne est roi.* You will therefore not be surprised if your one-eyed king for the day directs your attention this morning to railways, and especially to the question which is in the forefront of politics at this moment in almost every part of the world—the relation of railways to the State.

One word more by way of preface. I have said that these relations are being discussed at present all over the world. Ireland is no exception. There is at this moment sitting in Dublin a Viceregal Commission to inquire into the management of the Irish railways, and the question of State *versus* private ownership has been constantly brought up before it. As I am a member of that Commission, I evidently could not, even if I desired to do so, express here any personal views on a matter which is directly referred to me in an official capacity. But it seems to me that while it is necessary for me to refrain from discussing the particular question of the detailed remedies which the special historical and economic position of Ireland may be thought to require, it is possible to discuss the whole question in an abstract manner. I propose, therefore, to treat the subject in the main in two aspects: the first, the history in outline of the relations between railways and the State in different countries; and the second, the question of the factors which are of primary importance in any consideration of the matter.

Ever since the year 1830, when the dramatic success of the Liverpool and Manchester Railway first revealed to a generation less accustomed than our own to revolutionary advances in material efficiency the startling improvements in transport that railways were about to effect, theorists have discussed the question whether State or private ownership of railways be in the abstract the more desirable. But it is safe to say that in no country has the practical question, 'Shall the State own or not own the railways?' been decided on abstract considerations. The dominant considerations have always been the historical, political, and economic position of the particular country at the time when the question came up in concrete shape for decision.

The Belgian railways have belonged to the State from the outset, because they were constructed just after Belgium separated from Holland, and (the available private capital being in Holland and not in Belgium) King Leopold and his Ministers felt that, if the railways were in private hands, that would mean in Dutch hands, and the newly acquired independence of Belgium would be thereby jeopardised. Within the last few years this history has repeated itself, and the fact that the bulk of the Swiss railway capital was held in France and Germany was one main reason, if not *the* main reason, which induced the Swiss people to nationalise their railways.

In Germany seventy years ago the smaller States were regarded as the personal property of their respective Sovereigns, almost as definitely as Sutherlandshire is the property of the Duke of Sutherland. And it was therefore as natural that the Dukes of Oldenburg or Mecklenburg should make railroads for the development of their estates as that the Duke of Sutherland should build a railway in Sutherland.

Take, again, Australasia. In that region the whole of the railways, with negligible exceptions, now belong to the different State Governments, and the public sentiment that railways ought to be public property is to-day so strong that it is impossible to imagine any serious development of private lines. But at the outset the traditional English preference for private enterprise was just as strong there as it was at home, and it was only the fact that the whole of the available private capital was absorbed in the development of the goldfields and that, therefore, if railways were to be built at all, public credit must be pledged and English capital must be obtained, that caused the State to go into the railway business.

Take, once more, the case of Italy. In the days when Italy was only a geographical expression, the various Italian States experimented with railway management of all sorts and kinds. When, after 1870, Italy was unified, it was necessary to adopt a national railway policy, and the Italian Government instituted an inquiry whose exhaustiveness has not since been approached. The force of circumstances had indeed already compelled the Government to acquire the ownership of the railways, but the Commission reported that it was not desirable that the Government should work them. The railways were accordingly leased for a period of sixty years, running from 1884, to three operating companies, and it was provided that the leases might be broken at the end of the twentieth or the fortieth year. From the very outset a condition of things developed which had not been contemplated when the leases were granted, and for which the leases made no provision. Constant disputes took place between the Government and their lessees. Capital for extensions and improvements was urgently needed; neither party was bound to find it; and agreement for finding it on terms mutually acceptable was impossible of attainment. In the end the Government has been forced to cut the knot, to break the lease at the end of the first twenty years' period, and for the last two years the Italian Government has operated its own railways. But it is safe to say that an *à priori* preference for State management over private management played but scant part in the ultimate decision.

It is impossible to review, even in the merest outline, the railway history of all the countries in the world, but the instances already given will serve to illustrate my proposition that the position in each country depends not on abstract considerations, but on the practical facts of the local situation. Yet one cannot look round the world and fail to recognise that the connection between the railways and the State is everywhere becoming more intimate year by year. Whatever have been the causes, the fact remains that Italy and Switzerland have converted their railways from private to public. In Germany the few remaining private lines are becoming still fewer. In Belgium the process is practically completed. In Austria it is moving steadily in the same direction: four-fifths of the total mileage is now operated by the State. In Russia the story would have been the same, had it not been for the war with Japan. Even in France, whose railways have a very definite local and national history of their own, an Act for the purchase of the Western Railway by the State was passed last year by the Chamber of Deputies, and has now, after much contention, been passed by the Senate within the last few weeks. But it is not without interest to note that, though a majority both of deputies and of senators supported the Bill, the representatives of the district served by the company were by a large majority opposed to it, while the commercial community of the whole of France, as represented by the Chambers of Commerce, were almost unanimously hostile.[1] So far as can be seen at present, the purchase of the Western Railway by the State is not likely to be made a precedent for the general nationalisation of the French railways. Still, the broad fact remains that a series of railway maps of the continent of Europe, constructed at intervals of ten years, would undoubtedly show an ever-increasing proportion of State lines, and that the last of the series would exhibit the private lines as very far below the State lines both in extent and in volume of traffic.

A word ought to be said of Holland, not only because Holland is a country with free institutions like our own, but because the railway position of Holland is unique. The railways of that country were built partly by the State and partly by private enterprise, but the working has always been wholly in private hands. Some ten years ago, however, the Dutch Government bought up the private lines and rearranged the whole system. The main lines of the country are now leased to two operating companies, so organised that each company has access to every important town, and railway competition is now practically ubiquitous throughout Holland. So far there are no signs that the Dutch people are otherwise than satisfied with their system. Now compare this with France. The French Government, though it has hitherto, except on the comparatively unimportant State railways in the south-west of the country, stood aloof from the actual operation, has always kept entire control of railway construction and of the allocation of new lines between the several companies. And the French Government has proceeded on a principle diametrically opposed to the Dutch principle. In France railway competition has, as far as possible, been definitely excluded, and the various systems have been made to meet, not, as in Holland, at the great towns, but at the points where the competitive traffic was, as near as might be, a negligible quantity. Now that questions of competition and combination are to the fore in England, and seem likely to give very practical occupation to Parliament in the Session of 1909, the precedents on both sides are perhaps not without interest.

When we turn from the continent of Europe to the continent of America the position of affairs is startlingly dissimilar. The railways of America far surpass in length those of the continent of Europe, while in capital expenditure they are equal. State-ownership and operation of railways on the continent of America is as much the exception as it is the rule in Europe. In Canada there is one comparatively important State railway, the Inter-Colonial, about 1,500 miles in length. Though its earnings are quite considerable—about 20*l.* per mile per week—it barely pays working expenses. I may add that in all the voluminous literature of the subject I have never seen this line cited as an example of the benefits of State management. There is another small line, in Prince Edward Island, which is worked at a loss; and a third, the Temiskaming and Northern Ontario Railway, owned not by the Dominion but by the Provincial Government, which is too new to afford any ground for conclusions.

The Federal Government of the United States has never owned a railway, though some of the individual States did own, and in some cases also work, railways in very early days. They all burnt their fingers badly. But the story is so old a one that it would be unreasonable to found any argument on it to-day.

In Mexico, of which I shall have more to say directly, the State owns no railways. As for Central America, Costa Rica and Honduras have some petty lines,

[1] Further, it is common knowledge that the Senate only passed the Bill (and that by a majority of no more than three) because M. Clemenceau insisted that he would resign if it was not passed, and, though they disliked nationalisation much, they disliked M. Clemenceau's resignation more.

which are worked at a loss. Guatemala had a railway till 1904, when it was transferred to a private company. Nicaragua has also leased its lines. Colombia owns and works at a profit, all of which is said to be devoted to betterment, twenty-four miles of line.

In South America, Peru and Argentina own, as far as I am aware, no railways. The Chilian Government owns about 1,600 miles out of the 3,000 miles in the country. Needless to say private capital has secured the most profitable lines. The Government railway receipts hardly cover the working expenses. The Brazilian Government formerly owned a considerable proportion of its railway network of nearly 11,000 miles. Financial straits forced it some years ago to dispose of a large part to private companies, to the apparent advantage at once of the taxpayer, the shareholder, and the railway customer. About 1,800 miles of line are still operated by the Government, the receipts of which, roughly speaking, do a little more than balance working expenses. But it may be broadly said that the present Brazilian policy is adverse to State ownership and in favour of the development of the railway system by private enterprise.

The question of public ownership and operation was, however, raised very definitely in the United States only two years ago, when Mr. Bryan made a speech stating that his European experience had convinced him that it was desirable to nationalise the railways of the United States. For many weeks after, Mr. Bryan's pronouncement was discussed in every newspaper and on every platform, from Maine to California. Practically, Mr. Bryan found no followers; and to-day, though he is the accepted candidate of the Democratic party for the Presidency, the subject has been tacitly shelved. To some extent this may have been due to the ludicrous impossibility, if I may say so with all respect for a possible President, of Mr. Bryan's proposals. In order, presumably, not to offend his own Democratic party, the traditional upholders of the rights of the several States, he seriously suggested that the Federal Government should work the trunk lines, and the respective State Governments the branches. Even if anybody knew in every case what is a trunk line and what is a branch, the result would be to create an organism about as useful for practical purposes as would be a human body in which the spinal cord was severed from the brain. Mr. Bryan's proposal was never discussed in detail: public sentiment throughout the Union was unexpectedly unanimous against it, and it is safe to say that the nationalisation of the railways of the United States is not in sight at present.

But though nationalisation is nowhere in America a practical issue, everywhere in America the relations between the railways and the State have become much closer within the last few years. Canada a few years ago consolidated its railway laws and established a Railway Commission, to which was given very wide powers of control both over railway construction and operation and over rates and fares for goods and passengers. Argentina has also moved in the same direction. In the United States, not only has there been the passage by the Federal Congress at Washington of the law amending the original Act to Regulate Commerce and giving much increased powers to the Inter-State Commerce Commission, besides various other Acts dealing with subsidiary points, such as hours of railway employés, but scores, if not hundreds, of Acts have been passed by the various State Legislatures. With these it is quite impossible to deal in detail; many of them impose new pecuniary burdens upon the railway companies, as, for instance, the obligation to carry passengers at the maximum rate of a penny per mile. All of them, speaking broadly, impose new obligations and new restrictions upon the railway companies. Not a few have already been declared unconstitutional, and therefore invalid, by the Law Courts. And when the mills of American legal procedure shall at length have finished their exceedingly slow grinding, it is safe to prophesy that a good many more will have ceased to operate. But for all that, the net result of State and Federal legislation in the Sessions of 1906 and 1907 will unquestionably be that even after the reaction and repeal, which, thanks to the Wall Street panic of last year, is now in progress, the railways of the United States will in the future be subject to much more rigid and detailed control by public authority than there has been in the past. The reign of railway despotism, more or less benevolent, is definitely at an end; the reign of law has begun. It is only to be regretted that the quantity of the law errs as much on the side of excess as its quality on the side of deficiency.

Apart from its interest as a quite startling example of how not to do it, the recent railway legislation of the United States is only valuable as an indication of the tendency, universal in all countries, however governed, for the State to take a closer control over its railways. Much more interesting as containing a definite political ideal, worked out in detail in a statesmanlike manner, is the recent railway legislation of Mexico. One may be thought to be verging on paradox in suggesting that England, with seven centuries of parliamentary history, can learn something from the Republic of Mexico. But for all that I would say, with all seriousness, that I believe the relation between the State and the national railways is one of the most difficult and important questions of modern politics, and that the one valuable and original contribution to the solution of that question which has been made in the present generation is due to the President of the Mexican Republic and his Finance Minister, Señor Limantour.

Broadly, the Mexican situation is this: The Mexican railways were in the hands of foreign capitalists, English mainly so far as the older lines were concerned, American in respect of the newer railways, more especially those which constituted continuations southwards of the great American railway systems. The foreign companies, whether English or American, naturally regarded Mexico as a field for earning dividends for their shareholders. The American companies further, equally naturally, tended to regard Mexico as an annexe and *dépendance* of the United States. If they thought at all of the interest of Mexico in developing as an independent self-contained State, they were bound to regard it with hostility rather than with favour, and such a point of view could hardly commend itself to the statesmen at the head of the Mexican Government. Yet Mexico is a poor and undeveloped country, quite unable to dispense with foreign capital; and, further, it was at least questionable whether Mexican political virtue was sufficiently firm-rooted to withstand the manifold temptations inherent in the direct management of railways under a parliamentary *régime*. Under these circumstances the Mexicans have adopted the following scheme: For a comparatively small expenditure in actual cash, coupled with a not very serious obligation to guarantee the interest on necessary bond issues, the Mexican Government have acquired such a holding of deferred ordinary stock in the National Railroad Company of Mexico as gives them, not, indeed, any immediate dividend on their investment, but a present control in all essentials of the policy of the company, and also prospects of considerable profit when the country shall have further developed. The organisation of the company as a private commercial undertaking subsists as before. A board of directors, elected in the ordinary manner by the votes of shareholders, remains as a barrier against political or local pressure in the direction of uncommercial concessions, whether of new lines or of extended facilities or reduced rates on the old lines; but—and here is the fundamental difference between the new system and the old—whereas under the old system the final appeal was to a body of shareholders with no interest beyond their own dividend, the majority shareholder is now the Government of Mexico, with every inducement to regard the interests, both present and prospective, of the country as a whole.

Public ownership of railways is in theory irrefragable. Railways are a public service; it is right that they should be operated by public servants in the public interest. Unfortunately, especially in democratically organised communities, the facts have not infrequently refused to fit the theories, and the public servants have allowed, or been constrained to allow, the railways to be run, not in the permanent interest of the community as a whole, but in the temporary interest of that portion of the community which at the moment could exert the most strenuous pressure. The Mexican system, if it succeeds in establishing itself permanently—for as yet it is only on its trial—may perhaps have avoided both Scylla and Charybdis. Faced with a powerful but local and temporary demand, the Government may be able to reply that this is a matter to be dealt with on commercial lines by the board of directors. If, on the other hand, permanent national interests are involved, the Government can exercise its reserve power as a shareholder, can vote the directors out of office, and so prevent the continuance of a policy which would in its judgment be prejudicial to those interests, however much it might be to the advantage of the railway as a mere commercial concern.

The history whose outline I have now very briefly sketched shows, I think, that whereas there is everywhere a tendency towards further State control, the tendency towards absolute State-ownership and State-operation is far from being equally universal. I shall have a word to say presently as to the reasons why America shows no signs of intention to follow the example of continental Europe. Meanwhile it is well to notice that American experience proves also the extreme difficulty of finding satisfactory methods of control. Sir Henry Tyler said some five-and-thirty years ago in England, in words that have often been quoted since, 'If the State can't control the railways, the railways will control the State'; and President Roosevelt has again and again in the last few years insisted on the same point. 'The American people,' he has said in effect, 'must work out a satisfactory method of controlling these great organisations. If left uncontrolled, there will be such abuses and such consequent popular indignation that State-ownership will become inevitable, and State-ownership is alien to American ideas, and might cause very serious political dangers.'

Perhaps some of my hearers may remember Macaulay's graphic description of the passion that was aroused by Charles James Fox's proposed India Bill; it was described as a Bill for giving in perpetuity to the Whigs, whether in or out of office, the whole patronage of the Indian Government. The objection felt by American statesmen to handing over their railways to the National Government—for I think it may be taken for granted that if they were nationalised it would have to be wholly under federal management, and that the separate States could take no part in the matter—is in principle the same. There are something like a million and a half men employed on the railways of the United States, say roughly 7 or 8 per cent. of the voters. Americans feel that rival political parties might bid against each other for the support of so vast and homogeneous a body of voters; that the amount of patronage placed at the disposal of the Executive Government for the time being would be enormous; and that the general interests of the nation might be sacrificed by politicians anxious to placate—to use their own term—particular local and sectional interests. How far this fear, which is undoubtedly very prevalent in the States, is justified by the history of State railways in other countries is a question exceedingly difficult to answer. Dealing with State railways in the lump, it is easy to point to some against which the charge would be conspicuously untrue. To take the most important State railway organisation in the world, the Prussian system, no one, I think, can fairly deny that it has been operated—in intention at least, if not always in result—for the greatest good of the greatest number. But then Prussia is Prussia, with a Government in effect autocratic, with a Civil Service with strong *esprit de corps* and permeated with old traditions, leading them to regard themselves as the servants of the king rather than as candidates for popular favour. An American statesman, Charles Francis Adams, wrote as follows more than thirty years ago: 'In applying results drawn from the experience of one country to problems which present themselves in another, the difference of social and political habit and education should ever be borne in mind. Because in the countries of continental Europe the State can and does hold close relations, amounting even to ownership, with the railroads, it does not follow that the same course could be successfully pursued in England or in America. The former nations are by political habit administrative, the latter are parliamentary. In other words, France and Germany are essentially executive in their governmental systems, while England and America are legislative. Now the executive may design, construct, or operate a railroad; the legislative never can. A country therefore with a weak or unstable executive, or a crude and imperfect Civil Service, should accept with caution results achieved under a government of bureaus. Nevertheless, though conclusions cannot be adopted in the gross, there may be in them much good food for reflection.'

I am inclined to think that the effect of the evidence is that the further a Government departs from autocracy and develops in the direction of democracy, the less successful it is likely to be in the direct management of railways. Belgium is far from being a pure democracy; but compared with Prussia it is democratic, and compared with Prussia its railway management is certainly inferior. Popular opinion in Belgium seems at present to be exceedingly hostile to the railway administration; official documents assert that, while the service to the public is bad, the staff are scandalously underpaid, and yet that the railways are actually not paying their way. There was, it is true, till recently an accumulated surplus of profits carried in the railway accounts, but the official figures have been recently revised, and the surplus is shown to be non-existent.

The Swiss experiment is too new to justify any very positive conclusions being drawn from it; but this much is clear: the State has had to pay for the acquisition of the private lines sums very much larger than were put forward in the original estimate; the surplus profits that were counted on have not been obtained in practice; the economies that were expected to result from unification have not been realised; the expenditure on salaries and wages has increased very largely; and so far from there being a profit to the Federal Government, the official statement of the railway administration is that, unless the utmost care is exercised in the future, the railway receipts will not cover the railway expenditure.

The Italian experiment is still newer. It would not be fair to say that it proves anything against State management; but I do not think that the most fervid *Etatist* would claim that, either on the ground of efficiency or on the ground of economy, it has so far furnished any argument in favour of that policy.

If we wish to study the State management of railways by pure democracies of Anglo-Saxon type, we must go to our own Colonies. My own impressions, formed after considerable study of the subject and having had the advantage of talking with not a few of the men who have made the history, I hesitate to give. It is easy to find partisan statements on both sides; for example, in a recent article in the 'Nineteenth Century,' entitled 'The Pure Politics Campaign in Canada,' I find the following quotation from the 'Montreal Gazette'—a paper of high standing—dated May 27, 1907: 'Every job alleged against the Russian autocracy has been paralleled in kind in Canada. First, there is the awful example of the Inter-Colonial Railway, probably as to construction the most costly single-track system in North America, serving a good traffic-bearing country, with little or no competition during much of the year, and in connection with much of its length no competition at all, but so mishandled that one of its managers, giving up his job in disgust, said it was run like a comic opera. Some years it does not earn enough to pay the cost of operation and maintenance (I may interpolate that its gross earnings per mile are equal to those of an average United States railway), and every year it needs a grant of one, two, three, or four million dollars out of the Treasury to keep it in condition to do at a loss the business that comes to it. When land is to be bought for the road, somebody who knows what is intended obtains possession of it, and turns it over to the Government at 40, 50, and 100 per cent. advance. This is established by the records of Parliament and of the Courts of the land.'

Probably no one outside the somewhat heated air of Canadian politics is likely to believe this damning accusation quite implicitly; but even if there were not a word of truth in it—and that the management of the Inter-Colonial Railway is, for whatever cause, bad, appears, I think, clearly from the public figures—it is bad enough that such charges should be publicly made and apparently believed. Let me quote now from a document of a very different type referring to a colony very far distant from Canada: 'A Memorandum relative to Railway Organisation, prepared at the request of the Railway Commissioners of the Cape Government Railways, by Sir Thomas R. Price, formerly general manager of those railways, and now general manager of the Central South African (*i.e.*, Transvaal and Orange River) Railways, dated Johannesburg, February 22, 1907.

'Political Influences—Disturbing Effect of.

'The drawbacks in the management of the railways in the Cape that call for removal arise from the extent to which, and the manner in which, the authority of Parliament is exercised. They are twofold in their character, viz.:—

'(1) The practice of public authorities, influential persons, and others bent on securing concessions or other advantages which the general manager has either refused in the conscientious exercise of his functions, or is not likely to grant, making representation to the Commissioner (as the ministerial head of the Government), supplemented by such pressure, political influence, or other means as are considered perfectly legitimate in their way, and are best calculated to attain the end applicants have in view.

'(Many members of Parliament act similarly in the interests of the districts, constituents, or railway employés in whom they happen to be interested. It is by no means unknown for the requests in both classes of cases to coincide somewhat with a critical division in Parliament—present or in prospect—or otherwise something has occurred which is regarded as irritating to the public or embarrassing to the Government, and the desire to minimise the effect by some conciliatory act is not unnatural.)

'(2). The extent to which the fictitious, and often transitory, importance which a community or district manages to acquire obscures (under the guise of the Colony's welfare) the consideration of the railway and general interests of the Colony as a whole.'

(During the earlier period of my railway service in the Cape Colony few things impressed me more, coming as I had from a railway conducted on strictly business lines, than the extent to which the conduct of railway affairs was influenced by certain conditions. Nor was this impression lessened afterwards when, in the course of a conversation on the matter, Sir Charles Elliott mentioned to me that he had more than once told a late Railway Commissioner, 'The Government is powerful, but [mentioning the town and authority] is more powerful still.')

'I do not regard it as open to doubt that the Colony as a whole has suffered severely in consequence, the inland portions of the Colony particularly so; and that the need for a remedy is pressing if the railways are to be conducted as a business concern for the benefit of the Colony.

'Means of Securing Freedom from Political Influences.

'The necessity for the railways and their administration being removed from such an atmosphere, and treated as a most valuable means of benefiting the Colony as a whole, whilst not neglecting the interests of a district (but not subordinating the welfare of the whole Colony thereto), is pressing. That there should be an authority to refer to in case of real necessity, where the decision or action of the general manager is not regarded as being in the public interest, is also clear. But it is equally manifest that the Commissioner or the Government of the day, with political or party consideration always in view, is not the proper court of reference.

'Political Influences as affecting Construction of New Lines.

'There can be little doubt that in the Cape Colony political considerations have influenced the adoption of new lines and their construction—many, if not most of them, of an unprofitable character—without sufficient inquiry or information, often with scanty particulars, and possibly contrary to the advice of the officer afterwards entrusted with the construction and working of the line.

'Proposals for New Lines.—Procedure recommended.

'A material change is imperatively necessary in this respect, if only to ensure the solvency of the Colony.'

It is sometimes conceded that improper exercise of political influence may be a real danger where railways are managed under a parliamentary *régime* by a Minister directly responsible to Parliament; but that difficulty, it is said, can be got over by the appointment of an independent Commission entirely outside the political arena. History does not altogether justify the contention. The last Report of the Victorian State Railways gives a list of seven branches, with an aggregate length of 46 miles, constructed under the Commissioner *régime* at a cost of 387,000*l.*, which are now closed for traffic and abandoned because the gross receipts failed even to cover the out-of-pocket working expenses. It is not alleged, nor is it a fact, that those lines were constructed in consequence of any error of judgment on the part of the Commissioners. But in truth it is inherently impossible to use a Commission to protect a community against itself. In theory a Commission might be a despot perfectly benevolent and perfectly intelligent; in that case, however, it can hardly be said that the nation manages its own railways. But of course any such idea is practically impossible, because despots, however benevolent and intelligent, cannot be made to fit into the framework of an Anglo-Saxon constitution. In practical life the Railway Commission must be responsible to someone, and that someone can only be a member of the political Government of the day.

I have indicated what in America, where the subject is much more carefully considered than here, is regarded as a great obstacle to a State-railway system; but I have pointed out also that it is quite possible that statesmen fully alive to the dangers may yet find themselves constrained to risk them unless some satisfactory method of controlling private railway enterprise can be found. I do not think it can be considered that this has been done in England at the present time. In the main we have relied on the force of competition to secure for us reasonable service at not unreasonable rates; and as I still cherish a long-formed belief that English railways are on the whole among the best, if not actually the best, in the world, I am far from saying that competition has not done its work well. But competition is an instrument that is at this moment breaking in our hands. Within quite a few years the South Eastern Railway was united with the Chatham; the Great Southern has obtained a monopoly over a large part of Ireland; in Scotland the Caledonian and the North British, the Highland and the Great North have in very great measure ceased to compete. If the present proposals for the working union of the Great Eastern, the Great Northern and the Great Central go through, competition in the East of England will be absolutely non-existent from the Channel to the Tweed. And one can hardly suppose that matters will stop there. In fact, since this address was in type a comprehensive scheme of arrangement for a long term of years between the London and North Western and the Midland has been announced. We must, I think, assume that competition, which has done good work for the public in its day, is practically ceasing to have any real operation in regulating English railways.

For regulation, therefore, we must fall back on Government; but how shall a Government exercise its functions? Regulation may be legislative, judicial, executive, or, as usually happens in practice, a combination of all three. But we may notice that, as Mr. Adams points out, in Anglo-Saxon countries it is the Legislature and the Judicature that are predominant; whereas in a country like France, which though a democracy is bureaucratically organised, it is executive regulation that is most important. Now, the capacity of the Legislature to regulate is strictly limited; it can lay down general rules; it can, so to speak, provide a framework, but it cannot decide *ad hoc* how to fit into that framework the innumerable questions that come up for practical decision day by day.

The capacity of the Law Courts to regulate is even more strictly limited. For not only is it confined within the precise limits of the jurisdiction expressly conferred upon it by the Legislature, but further, by the necessity of the case, a court of law can only decide the particular case brought before it; a hundred other cases, equally important in principle, and perhaps more important in practice, may never be brought before it at all. Even if the Court had decided all the principles, it has no machinery to secure their application to any other case than the one particular case on which judgment was given. There was a case decided thirty years ago by our Railway Commission, the principle of which, had it been generally applied throughout the country, would have revolutionised the whole carrying business of Great Britain. It has not been so applied, to the great advantage in my judgment of English trade. Further, the great bulk of the cases which make up the practical work of a railway: 'What is a reasonable rate, having regard to all the circumstances, present and prospective, of the case? Would it be reasonable to run a new train or to take off an old one? Would it be reasonable to open a new station, to extend the area of free cartage, and the like?'—all these are questions of discretion, of commercial instinct. They can only be answered with a 'Probably on the whole,' not with a categorical 'Yes' or 'No,' and they are absolutely unsuitable for determination by the positive methods of the Law Court with its precisely defined issues, its sworn evidence, and its rigorous exclusion of what, while the lawyer describes it as irrelevant, is often precisely the class of consideration which would determine one way or other the decision of the practical man of business.

It seems to me, therefore, that both in England and in America we must expect to see in the near future a considerable development of executive government control over railways.

This is not the place to discuss in detail the form that control should take, but one or two general observations seem worth making. The leading example of executive control is France; in that country the system is worked out with all the French neatness and all the French logic. But it is impossible to imagine the French principle being transplanted here. For one thing, the whole French railway finance rests upon the guarantee of the Government. The French Government pays, or at least is liable to pay, the piper, and has therefore the right to call the tune. The English Government has not paid, and does not propose to pay, and its claim to call the tune is therefore much less. Morally the French Government has a right—so far at least as the railway shareholders are concerned—to call on a French company to carry workmen at a loss; morally, in my judgment at least, the English Government has no such right. But there is a further objection to the French system: the officers of the French companies have on their own responsibility to form their own decisions, and then the officers of the French Government have, also on their own responsibility, to decide whether the decision of the company's officer shall be allowed to take effect or not. The company's officer has the most knowledge and the most interest in deciding rightly, but the Government official has the supreme power. The system has worked—largely, I think, because the principal officers of the companies have been trained as Government servants in one or other of the great Engineering Corps, des Mines or des Ponts et Chaussées. But it is vicious in principle, and in any case would not bear transplanting.

What we need is a system under which the responsibility rests, as at present, with a single man (let us call him the general manager), and he does what he on the whole decides to be best, subject however to this: that if he does what no reasonable man could do, or refuses to do what any reasonable man would do, there shall be a power behind to restrain, or, as the case may be, to compel him. And that power may, I think, safely be simply the Minister—let us call him the President of the Board of Trade. For, be it observed, the question for him is not the exceedingly difficult and complicated question, 'What is best to be done?' but the quite simple question, 'Is the decision come to which I am asked to reverse so obviously wrong that no reasonable man could honestly make it?'

And even this comparatively simple question the President would not be expected to decide unaided. He will need competent advisory bodies. Railway history shows two such bodies that have been eminently successful—the Prussian State Railway Councils and the Massachusetts Railroad Commission. Wholly unlike in most respects, they are yet alike in this: their proceedings are public, their conclusions are published, and those conclusions have no mandatory force whatever. And it is to these causes that, in my judgment, their success, which is undeniable, is mainly due. Let me describe both bodies a little more at length.

There are in Prussia a number (about ten, I think) of District Railway Councils, and there is also one National Council; they consist of a certain number of representative traders, manufacturers, agriculturists, and the like, together with a certain number of Government nominees; and the railway officials concerned take part in their proceedings, but without votes. The Councils meet three or four times a year, their agenda paper is prepared and circulated in advance, and all proposed changes of general interest, whether in rates or in service, are brought before them, from the railway side or the public side, as the case may be. The decision of the Council is then available for information of the Minister and his subordinates, but, as has been said, it binds nobody.

The Massachusetts Railroad Commission is a body of three persons, usually one lawyer, one engineer, and one man of business, appointed for a term of years by the Governor of the State. Originally the powers of this Commission were confined to the expression of opinion. If a trade, or a locality, or indeed a single individual, thought he was being treated badly by the Massachusetts Railroad, he could complain to the Commission; his complaint was heard in public; the answer of the railway company was made there and then; and thereupon the Commissioners expressed their reasoned opinion. The system has existed now for more than thirty years, and it is safe to say that, with negligible exceptions, if the Commission expresses the opinion that the railroad is in the right, the applicant accepts it; if the Commission says that the applicant has a real grievance, the railroad promptly redresses it on the lines which the Commissioners' opinion has indicated. The success of the Commission in gaining the confidence of both sides has been so great that of late years its powers have been extended, and it has been given, for example, authority to control the issue of new capital and the construction of new lines. But on the question with which we are specially concerned here, the conduct of existing railway companies as public servants, it can still do nothing but express an opinion; and it may be added that the Commission itself has more than once objected to any extension of that power.

Mr. Adams, from whom I have already quoted, was the first Chairman of the Commission. He has described their position as resting 'on the one great social feature which distinguishes modern civilisation from any other of which we have a record, the eventual supremacy of an enlightened public opinion.' That public opinion is supreme in this country, few would be found to deny; that public opinion in railway matters is enlightened, few would care to assert. But given the enlightened public opinion, one can hardly doubt that it will secure not merely eventual but immediate supremacy. In truth, as Bagehot once pointed out, a great company is of necessity timorous in confronting public opinion. It is so large that it must have many enemies, and its business is so extended that it offers innumerable marks to shoot at. It is much more likely to make, for the sake of peace, concessions that ought not to be made than it is to resist a demand that reasonable men with no personal interest in the matter publicly declare to be such as ought rightly to be conceded.

To sum up in a sentence the lesson which I think the history we have been considering conveys, it is this: Closer connection than has hitherto existed between the State and its railways has got to come, both in this country and in the United States. Hitherto in Anglo-Saxon democracies neither State ownership nor State control has been over-successful. The best success has been obtained by relying for control, not on the constable, but on the eventual supremacy of an enlightened public opinion. Nearly twenty years ago, in the pages of the 'Economic Journal,' I appealed to English economists to give us a serious study of what the Americans call the transportation problem in its broad economic and political aspects. Since then half-a-dozen partisan works have appeared on the subject, not one of them, in my judgment, worth the paper on which it is printed; but not a single serious work by a trained economist. And yet such a work is to-day needed more than ever. Let me once more appeal to some of our younger men to come forward, stop the gap, and enlighten public opinion.

The following Papers were read:—

1. *The needed Reform in the Assessment of Railways for Local Taxation.* *By* F. OLIVER LYONS, *M.A.*

Protection against over-assessment is enjoyed by all ratepayers except railway companies. The railway companies can, in common fairness, claim the same protection against over-assessment. The 'cumulo' principle of assessment is invulnerable. Details are separable from the principle; no disparagement of the details affects the principle. What has actually happened under the 'parochial' system of assessment is that the English and Welsh railways were over-assessed in 1906 by at least 3,000,000*l.* sterling. Under the 'cumulo' method of assessment the railways would have been saved in rates, say, 700,000*l.* per annum. The net annual value of each railway as a whole would have been the maximum limit of rateable value, and hence the necessary guarantee against over-assessment would have existed. Large sums which were spent by the companies on rating appeals would have been saved; unless total net annual value warranted an increase in the total rateable value, any increase in the latter, made on account of improvements at stations, would have had to be taken off elsewhere. The vital defect in the 'parochial' system overshadows all its other defects, since the total amount of their assessment is really all that seriously concerns a railway company. It was recommended by the Royal Commission on Local Taxation that a central authority should be appointed who would value each railway by the 'cumulo' method. The rateable value of the railways, as ascertained by the 'parochial' system, is nothing better than guesswork, and there is much uncertainty about the 'parochial' system. The responsibility for the existing state of affairs rests with the companies' rating surveyors, whose evidence before the Royal Commission on Local Taxation was hostile to the 'cumulo' principle, and their hostility was founded on the imperfection of a detail which was of no importance to the companies. The explanation of the attitude taken up by the companies' rating surveyors. The essential data for assessment purposes are not compiled by the railway companies. No responsible surveyor would contend that the railways are not over-assessed, because definite and final proof that they are is not obtainable from the railway returns. The chairmen of the companies have never had the only information which would enable them to show the shareholders the true assessment position. The author concluded by discussing the attitude of outside interests towards the 'cumulo' method of assessment, the remedy open to the railway companies, and the problem to be solved.

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2. *Nationalisation of Irish Railways.* *By* J. O'CONNOR.

Compulsory purchase of the Irish railways by the State would only be justified if it is clear that a substantial benefit would thereby be secured to the country and on the terms of full compensation being made to the shareholders and stockholders.

If the benefit is small and uncertain, or if the shareholders were not adequately compensated, the operation would be indefensible.

Anything less than a reduction of, say 25 per cent. in rates and fares (taken as an average), would be merely trifling with the subject; even that percentage would produce little or no effect on the general prosperity of the country, and give little aid in competition with other countries—because the distances covered by the Irish railways are comparatively short, and the gross freights little; because the staple products of the country are valuable in comparison with the rate; because, as regards the general body of the traffic, the rates are paid by manufacturers and they fall to a large extent on imported goods; and because only the local proportion of cross-channel rates could be affected.

Taking 25 per cent., for the purpose of illustration, as representing the average reduction of rates and fares, which might be more in one class of traffic and less in another, it would represent a sum of 1,045,000*l.* on the receipts for the year 1906 to be made good by profit on purchase, by saving in working expenses, by increased traffic, or in default by the taxpayer.

Three modes of providing payment for the shareholders and stockholders have been proposed:—

First, cash raised on the credit of the State, presumably Imperial credit.
Second, by Imperial stock, say Consols.
Third, by guaranteed charge on the taxes of Ireland.

As regards the first—that is, cash—an Act of 1844 authorises the purchase of all railways constructed subsequent to that date at twenty-five years' purchase of three years' average net profits, with power for railways to arbitrate claims for additional payment grounded on their prospects (which power many railways would be likely to invoke). This in the case of the Irish railways would require about 45,000,000*l.* cash—a sum which could not be raised without disturbing the money markets to such an extent as to render any accurate calculation on its results impracticable.

Second, as regards Consols, the transaction would be simple financially, only requiring the issue of sufficient Consols to produce a net income of 1,647,550*l.* *plus* some consideration for stocks on which no dividend was paid. This would leave no profit. Both these modes of purchase would involve the railways being controlled and managed by the Treasury similarly to the telegraphs and posts.

The third mode of payment would be a railway stock charged primarily on the net receipts of the railways and guaranteed by the rates of the country, sufficient to produce the net income of 1,647,550*l.* *plus* a percentage for dead stocks. This security would be inferior in capital value to the railway stocks at present on the market; substantial bonuses should be paid, and dead stocks must be considered, and as a consequence the financial transaction would result in a loss instead of a profit.

The control of the Treasury and of a Minister of State would not be popular, and probably would not be acceptable in Ireland. Increased facilities would be expected and would be almost impossible to obtain at the expense of the State, and compensation for injury or loss of goods, or for personal injuries, would also be most probably ignored.

The result would therefore be that unless a cash purchase were carried out with extraordinarily good fortune, no part of the 1,045,000*l.* would be provided; and in the other two modes of financing, the deficit would be increased instead of diminished.

With regard to the savings, I have made careful estimates, guided by the experience of twenty-five years of railway life. These estimates indicate that on purchase by the State on either the first or second basis a saving in working expenses amounting to about 73,000*l.* per annum could be effected, but that if the railways were under popular control in Ireland that saving would be reduced to about 25,000*l.*, unless in both cases large reductions of train service and other facilities were made which would be the reverse of the object for which the purchase is advocated.

73,000*l.*, or call it 100,000*l.* in round numbers, would be 2½ per cent. off the rates and fares, a wholly inadequate and ludicrous result to justify such a project, and even were there savings of 400,000*l.* per annum only 10 per cent. would be taken off the rates and fares.

There remains, then, only increase of traffic to recoup the loss: 25 per cent. reduction would mean that for every 100*l.* at present earned, 75*l.* would be earned in future. Taking the working expenses at 60 per cent., it would mean that 15*l.*, or one-fifth profit, would arise on every 75*l.* of receipts, so that to obtain 1,647,550*l.* of profit the gross receipts should be five times that amount, viz., 8,237,750*l.*, practically double the present receipts, which for the year 1906 were 4,186,422*l.*, or, say, in round numbers 8,000,000*l.*, after deducting the odd figures for light mileage and other savings.

To carry the additional traffic would require additional rolling-stock, costing about 3,301,312*l.*, and also increased station and general accommodation, costing about 2,000,000*l.* more, giving about, say, 5,000,000*l.* new capital to be raised, which at 4 per cent. would cost 200,000*l.* per annum, involving another million of traffic receipts to cover—in all requiring traffic receipts of 9,000,000*l.*, which is wholly out of the question in this country.

The result is that to make even the not extravagant reduction of 25 per cent. would involve an average taxation of over 30,000*l.* a year on every county in Ireland, and as the country is already taxed beyond its financial abilities, and the contributions in aid of local taxation made out of Imperial taxation under the various Acts of Parliament affecting the question have been pledged as security for the interest on the advances made by the Treasury to finance the Land Act, this addition to the taxation, if ever possible, would be extremely inopportune at the present moment.

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3. *On certain Peculiarities of Small Duties on Imports and Exports.*[1] *By* Professor F. Y. Edgeworth, *D.C.L.*

Mr. Bickerdike's theory that 'advantage is always possible in normal circumstances from either import or export taxation when the taxes are small enough,'[2] can hardly be proved by verbal argument, involving, as it does, the mathematical principle that when a variable magnitude is in the neighbourhood of a maximum, the increment of the variable corresponding to a small finite increment of a variable on which it is dependent is likely to be particularly small. The case excepted by Mr. Bickerdike as very unlikely is practically impossible. The proof of the theory is strict when there is fulfilled the condition that the collective demand (at a price) is the sum of the amounts demanded by each individual, and the collective supply is similarly formed. But even without this datum, the theory is highly probable. For (1) the condition may be assumed as the 'least arbitrary supposition';[3] (2) small taxes, such as the theory mostly prescribes, may be inadequate to overcome the friction resisting a change of scale and plan in supply and demand; (3) failing the condition, the truth of the theory depends on a certain coefficient having a value which it probably has. Light rather than fruit is to be expected from the theory.

FRIDAY, SEPTEMBER 4.

The following Papers were read:—

1. *The Financial Side of Irish Land Purchase.* *By* Professor C. F. Bastable, *M.A., LL.D.*

Different problems are involved in the Land Question—political, social, and financial—and the financial side is of growing importance. This is due to the Act of 1903. The measure is 'based on finance.' Its promoters failed to recognise the rapidity of operations and the possible changes in economic conditions. The actual progress of land purchase will speedily exhaust the fund provided to meet losses.

Suggested remedies:—

(1) Substitution (in whole or part) of stock for cash as payment to sellers There are objections to this course.

(2) Issue of short-term notes instead of stock. The absence of real relief and financial danger by this expedient were dwelt upon.

(3) Taking up of Irish Land Stock by National Debt Commissioners. Only

[1] Published in the *Economic Journal*, September 1908.
[2] *Economic Journal*, vol. xvi. p. 529.
[3] Bickerdike, *Economic Journal*, vol. xvii. p. 583.

slight relief would be obtainable in this way; the connection with the Sinking Fund would be unsatisfactory.

More fundamental remedies are :—

(4) Alteration of $2\frac{3}{4}$ per cent. stock to 3 per cent., with corresponding increase of purchasers' annuities. In this case there would be a necessary loss to landlords and tenants. The claim that the State is bound by the Act of 1903 was examined.

(5) Transfer of the State grant from bonus fund to an insurance against loss on issues. Objections are raised on the ground of unequal treatment and hindrance to sales.

Possibly methods 4 and 5 might be combined.

(6) Further assistance from the British Exchequer. The unexpected magnitude of the transaction may justify a proportional increase in financial aid. Possibly compensation may be obtained through administrative reforms.

The land-purchase policy is closely dependent on general economic conditions. Changes in the latter are accountable for the difficulties that have arisen. Particular interest of Irish landlords.

Governmental action is limited by the above indicated conditions. The special difficulties arising out of war finance were examined.

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2. *The Housing of the Working Classes in Ireland. By* N. J. SYNNOTT.

The problem covers not only housing of town and country labourers, but also that of artisans and skilled labourers in towns and of many farmers and cottiers in the country. The deficiency of accommodation in Ireland is not due to the same causes as was the deficiency in many English districts—*e.g.*, increase of population or shifting of labour centres. The general standard of accommodation is lower than in England, and there has not been here the same rigorous enforcement of sanitary laws against owners or occupiers. Private effort or capital has not supplied in Ireland the deficiency of sanitary houses either in town or country.

The following public inquiries have been made: Richmond and Bessborough Commissions (1879–1882); Select Committee on Agricultural Labourers, Ireland (1884); Royal Commission on the Housing of the Working Classes, Ireland (Urban Dwellings) (1885); Royal Commission on Labour (1894); Viceregal Committee on Housing (1900). The Report of 1885 proved to be wrong in its diagnosis by results. The Report of 1894 was not acted upon in regard to housing and sanitation.

The state of house accommodation in cities and towns in Ireland may be gathered from the Census returns, the Reports of Assistant Commissioners in 1894, and the Local Government Board Inspectors' Reports; 750,000*l.* has been the total amount of loans for housing, and 7,631,000*l.* the total amount of loans for sanitation, water-supply, &c. The existing machinery for securing sanitation, removing insanitary houses, and supplying new houses are the Public Health Acts, the Housing of the Working Classes Acts, and certain local Acts. A short analysis was made of the purview and machinery of these Acts—the aim of the Legislature and experience in their actual working.

It is questionable whether the Public Health Acts are suitable for Irish rural districts or small towns and villages. Besides, they are adoptable only, and in many districts they have not been adopted. Even where adopted they are often a dead letter. There is no adequate system of inspection and report. The staff is neither adequate, effective, nor independent of local influences. Proceedings are not taken to abate nuisances or orders are not enforced. Local bodies are inert, or do not like doing unpopular things, or increasing the rates.

The machinery of Parts I. and II. of the Housing of the Working Classes Act is far too elaborate and expensive; this has been found even in England. In rural districts they seem quite unsuitable, and are a dead letter. Besides, there is no practical means of compelling local bodies or officers to do their duties under Parts I. and II. of the Acts. As to Part III. (giving power to local authorities to build, let, and manage workmen's houses), reasons were given to show that the problem is much too large for local bodies to solve by construction schemes; that the burden on the rates would be prohibitive, and a partial attempt thus to provide houses would deter private effort and would lead, in the end, to a further deficiency of houses. The Bill of this Session, 'Housing of the Working Classes (Ireland) Bill,' was criticised. A subsidy of 190,000*l.* of public money is given by the Bill. The basis of the proposal that municipalities should undertake the task of providing cheap houses for the working classes is letting at low and unremunerative rents. How should the gap be filled? It was argued that the functions of local bodies should be mainly regulative and preventive—*i.e.*, removal of nuisances, insanitary buildings, securing light, air, water, cleanliness, &c., but not the construction and supply of new houses. These functions might include compulsory purchase of sites, but should otherwise be mainly dis-housing, not housing. State aid might well, under certain conditions, be safely given to private effort in rebuilding where sites are cleared. If these regulative functions are to be generally used and effective, there must be a control of the local bodies and a more thorough and efficient inspection. Examination was made of the principles of the new English Housing Bill—a Government measure, not, however, applicable to Ireland (Housing and Town Planning Bill, brought in by Mr. John Burns). It was argued that the principles of that Bill might well be adapted to Ireland.

The plan of providing houses for labourers in Ireland through local bodies, under the Labourers Acts, however justifiable as an improvement or example, cannot solve the whole problem, but may seriously hinder the final solution of the main part of it. The economic and financial results of these Acts were outlined and compared with the area of problem to be solved as illustrated by statistics. The author dealt with the results of past working of the Labourers Acts and the possible effect of the new schemes proposed under the Act of 1906, specially noticing financial consequences and the effect on the rates, and traced the economic outcome with reference to the supply of labour and the relation between labourer and farmer. The present policy was contrasted with that of schemes of migration and the compulsory paring down of large holdings recently proposed. It was argued that the rational and equitable policy was to make the employer of labour and owner of insanitary property supply proper houses for workmen and tenant; and that the State should step in only in the last resort. The owner of insanitary property now goes free, or benefits by getting cheap houses paid for out of the rates. The need of enforcement of the Public Health Acts was emphasised, and also that loans should be given to the owner or employer under certain conditions, the local body being the intermediary, and the rates the security to the Government for the loan. The author urged the need for a more central system of medical inspection and for power to compel local bodies to inspect and enforce abatement of nuisances, &c. It was contended that the State should not embark on a policy of supplying houses out of public money, unless it can supply *all* who have equal claims.

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3. *The Depopulation of Ireland.* *By* ROBERT H. MURRAY, *M.A.*

From 1801 to 1846 the population of Ireland steadily increased, while from 1847 to the present time it has just as steadily diminished. The year of the great famine marks a dividing line in Irish history. Before 1846 the agriculture of this country was largely of the tillage order, while since that date it has assumed the pastoral form.

The dominant influence in Irish industrial history for the early forty-five years of the nineteenth century was Foster's Corn Law. It is not perhaps an over-statement to say that no Act so profoundly modified our history as the far-reaching measure brought forward by Foster in 1784. Its author modelled it on the English corn laws as they had existed since 1688. The change from pasturage to tillage came at a time when it proved peculiarly suitable to the requirements of England, where the industrial revolution was making rapid strides. Consequently the demand across the Channel for corn enormously increased, and the supply came largely from Ireland. With the rise in the price of corn came the inevitable influence in the marriage rate. In 1811 the population was 5,956,466; in 1821 it was 6,801,827; in 1831 it was 7,767,401; in 1841 it was 8,199,853; and in 1845 it was 8,295,061.

With the fall of prices consequent upon the conclusion of the Napoleonic wars the hard years began to come. The tide of emigration flowed in 1826 and 1827, for the landlord attempted to consolidate the small holdings. The development of transport coincided with the opening of the Mississippi valley, and these changes promoted the growth of free trade in England. What gravely affected Ireland since 1846 was not the potato famine, but the abolition of the corn laws. A student of eighteenth-century Irish history at once perceives that Ireland passed through many famines. The emigration statistics tell the tale of some of the results of the change in English commercial policy.

This country flourished before 1846, but its state was entirely artificial. No real dependence could therefore be placed on what had happened. With the abolition of the corn laws the fictitious industrial life of the country was at once evident. When free trade began, for a time this land did not prosper, but at last some measure of success has been vouchsafed. To-day an Irishman feels at least that his hardly-won industrial triumphs are all his own, that they are largely independent of State control and State support.

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4. *The Economic Ideal and its Application to Countries or Nations. By* Professor Edwin Cannan, *M.A., LL.D.*

The general economic ideal is maximum material welfare, not of course lumped in an unintelligible aggregate, but reckoned in the ordinary way, *per capita*. If this be straightway applied to countries, it will often conflict with the national or political ideal of a population large enough for 'security,' and for certain other purposes such as the maintenance of the national language and literature (if any), but this objection may be set aside as non-economic. Even on purely economic grounds, however, the application of this ideal to countries cannot be justified. Countries are no longer 'worlds in themselves.' The greater sale of goods in international markets, coupled with easier migration and regulation of population, is tending to wipe out international differences of earnings. Consequently differences in material welfare as between countries is coming to depend more and more upon the same cause as the differences between different parts of the same country—that is, on the distribution over the globe of persons owning property and performing the different classes of labour. Those countries are richest which either contain the largest proportions of the persons who own considerable portions of the property of the world, or contain the largest proportions of the people who do the best paid classes of work. So if the ideal of the maximum material welfare of its inhabitants be set up for each country, the most urban countries will always appear nearest the ideal, which is absurd. A country approaches the economic ideal just in so far as it is best utilised for the benefit of the world community.

MONDAY, SEPTEMBER 7.

The following Report and Papers were read:—

1. *Interim Report on the Amount of Gold Coinage in Circulation in the United Kingdom.*

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2. *International Agreements on Labour Legislation.* *By* Professor E. Francke, *Ph.D.*

The question how to effect by means of international conventions a uniform adjustment of the laws and regulations that are intended to serve for the protection of life, health, and morality of industrial workpeople is as old as the laws themselves for the protection of the working-classes. England was the country of origin of both: both are connected with the name of R. Owen (1815) whose labours were continued by the Elsass manufacturer, Dr. Legrand (1837–1859). Representatives of science, of workmen's organisations and statesmen encouraged them. In 1889 the Federal Council of Switzerland issued invitations to the governments of the industrial countries of Europe to attend a conference when the German Emperor asked to be permitted to take the lead (Workmen's rescripts of February 4, 1890). In the spring of 1890 the delegates of thirteen European countries—amongst them Germany, Great Britain, France, Austria, and Italy—met together in order to consider the regulation of work in mines, the observance of Sunday, and the employment of children and women. Although general agreement was arrived at on many points, no definite treaties were made—only wishes were expressed.

At the same time, this Conference of Berlin gave immense encouragement to the progress of the idea of workmen's protection, and, but for it, private initiative, which now stepped in, would never have been attended with success. In August 1897 a workmen's congress, held at Zurich, which was attended by representatives of a great number of countries, demanded the establishment of an international office for the protection of workpeople; and a meeting of representatives of social-politics from Belgium, Holland, France, Germany, Austria, and Switzerland, held at Brussels in October 1897, voiced similar aspirations. Delegates of both workmen and social politicians met together in 1900 at Paris in order to found the International Association for the legislative protection of workpeople. The seat of this association is Basle, twelve countries as sections adhere to it: Switzerland, Germany, Great Britain, France, Italy, Austria-Hungary, Belgium, Holland, Denmark, Spain, and the United States of America. The governments of almost all these countries have joined the Association—unfortunately the British Government have not yet done so—and grant subsidies to it. Every two years the delegates of the governments and sections meet for the purpose of discussing labour questions—the next meeting will take place at Lucerne, September 27–30, 1908.

The Association aims at encouraging the study of labour legislation of all countries and at preparing international diplomatic treaties connected with the protection of workpeople. The International Office of Labour, inaugurated at Basle in May 1901, serves both these aims, and, as a scientific central bureau, collects material and publishes bulletins in German, French, and English; the office also supplies information and gives an opinion on matters laid before it. The conference of delegates commenced in 1901 with the consideration of the prohibition of industrial night-work for women, the means of combating the dangers arising from the use of poisons in factories, and international workmen's insurance. On the motion of the Association the Swiss Federal Council invited the Governments of the countries of Europe in 1904 to meet in a conference which led in 1905 and 1906 to the conclusion of two treaties containing the following provisions:—

1. Night-work for women in factories is prohibited; a minimum pause of two hours during the night is fixed. Thirteen countries signed this treaty—namely, Germany, Austria, Belgium, Denmark, Spain, France, Great Britain, Italy, Luxemburg, Holland, Portugal, Sweden, and Switzerland.

2. The use of white phosphorus in the manufacture of matches is prohibited. Seven countries signed this treaty—namely, Germany, Denmark, France, Italy, Luxemburg, Holland, and Switzerland. Six countries (namely, Austria, England, Belgium, Sweden, Portugal, and Spain) held themselves aloof.

Already before these agreements, in 1904, France and Italy had concluded a treaty—with the co-operation of the Association—allowing their workpeople to participate mutually in the benefits of social insurance and protective regulations, and in the promoting of labour legislation in the two countries. Various countries (Germany, France, Belgium, Holland, Luxemburg) have come to terms concerning individual questions of workman's insurance, or in concluding commercial treaties, and have agreed upon regulations affecting the mutual protection of their workpeople (Germany, Austria-Hungary, Italy, and Switzerland). The International Association is continuing to carry on its work. Prohibition of night-work for youths; children's work and the protection of children; regulation of home-industry; introduction of measures against dangers from the use of poisons (lead); international accident insurance; maximum length of workdays—these are the subjects for the next conference, which, it is hoped, will move a step forward towards the conclusion of new international treaties.

Anybody who sees in the protection of workmen of his own country an act of obedience to the call of justice and also a necessity for the maintenance of the health and the efficiency of the working classes, will also recognise in international treaties concerning labour legislation a furtherance of humanity and an effective adjustment of competition. It is the interest of every civilised nation and of every industrial country to promote the realisation of these aims.

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3. *Proposals for an Economic Survey of the United Kingdom.* *By* HENRY W. MACROSTY, *B.A.*

An economic survey of the United Kingdom is proposed, not only as a task useful in itself, but also as one which is a special duty of the economists, while its execution would rescue the economic profession from its present position of disregard. Economists are considered by a great mass of people to be not only men of mere theory, but also theorists who have derived their beliefs from the study of industrial conditions long past. Whether this charge is true or false, its effects are the same. If economic theories were such as to give their students a command over industrial conditions, their opinions would be regarded as authoritative by statesmen and manufacturers. This is far from being the case. In fact, the weakness of economics is that its generalisations, however true, are so general that they are remote from the problems of everyday life, and the two cannot be brought into any close relation with each other. It is therefore necessary to leave theory on one side for a time and ascertain what are the facts of the industrial world and how they have come to be what they are. This done, it will be possible to test and complete our theories and to set forth those subordinate generalisations which will connect them with the questions of everyday life.

An economic survey is particularly necessary for the two new departments of economics. Business economics, which treats of the conditions of business success; and social economics, which is concerned with the relations between the individual, the trade, and the nation. The work has, indeed, been begun by individuals, who have dealt with special problems or the condition of particular classes; but the most essential feature of the present proposals is that any trade which is dealt with should be treated as a whole and described and analysed in all its parts and relations. Only then can we tell how that particular trade stands.

The survey of a trade will fall into the following main divisions—sources of raw materials, methods of manufacture, machinery of sale, organisation, position in the State. The sources of information are technical works, technical journals, and journals of scientific societies, trade papers, prospectuses, company reports, blue-books, and personal investigation. The Economic Section should appoint an organising committee, which would institute advisory committees of manufacturers to assist in obtaining the necessary information, overcoming trade jealousies, and preventing the publication of trade secrets. The details of the investigation would have to be worked out by the general committee, but success depends upon securing efficient investigators and enough money. Still, to achieve a survey of even one industry would be useful.

4. *Industrial Evolution in the Cutlery Industry.* *By* G. I. H. Lloyd, *M.A.*

The transition from handicraft to factory organisation of industry may be conveniently traced in the development of the cutlery trades, especially in England and Germany, where the trades have been mainly localised in a single town in each case, and where a definite international parallelism can be established. The introduction of steam-power, which is usually regarded as the turning point between the old and the new types of industrial organisation, had no special significance where manual skill retained its predominance. Just as there were factories before the steam-engine, so there are to-day numbers of occupations in which the domestic producer is found in possession of his special trade or process. A generation ago the cutlery trades were for the most part semi-domestic, being principally carried on by forgers, cutlers, and grinders, who rented their own work-places and worked on their own tools, thus retaining to some extent the independence and the capitalistic responsibilities of the old guild craftsman, and turning out goods in the production of which machinery played an insignificant part. The gradual introduction of mechanical methods as supplementary to, or as substitutes for, the almost bare-handed skill of the old system is gradually producing the true factory type of organisation. In fact, the factory system, though long retarded, is now making rather rapid progress, involving a steady transition from independent master workman to wage-worker, and the increasing prominence of the capitalist employer. The artisan has in the past clung tenaciously to his independence, but the semi-capitalistic functions which fall on him prove a severe burden in times of indifferent or declining trade, and he is now generally not unwilling to resign them. The change in the status of the worker affects the power and influence of the labour unions. These made their appearance in Sheffield early in the eighteenth century, marking the practical exclusion of the journeymen from their corporate rights as members of the Cutlers' Company. During the first half of last century they were powerfully organised, and became in some cases despotic and even ruthless in enforcing their regulations on recalcitrant masters and men, and earned an unenviable reputation. Though still organised on sectional lines, they are beginning to look to federation and consolidation as necessary to maintain and increase their influence. The corresponding unions in Germany are more effectively organised, the established price-lists are enforced, and elaborate machinery for conciliation has resulted from their activity. Both in Sheffield and in Solingen machinery has taken a firm hold of the forging process and of the work of preparing the separate portions of a knife-handle. Even the cutler who puts the pieces together and builds up a complete article is becoming more and more dependent on mechanical aids, and finds his work increasingly subdivided. Grinding remains for the most part the stronghold of simple hand industry, for, though automatic grinding has been partially applied to grinding files and to preparatory work on razors and knives, no device for the successful production of an edge has yet appeared.

The basis of the prevailing wage rates is still the time-honoured piecework price-lists; but though these are not yet discarded, neither are they strictly observed, but in most cases are subject to varying discounts. In the newer forms of the industry there is a steady increase of time wages, but of course this cannot apply to the considerable body of outworkers, whether grinders, file-cutters, or cutlers. Meanwhile the 'little master,' employing a small team of men in a single occupation, or giving out work in turn to those undertaking the various processes, and then himself trading his wares away, has not disappeared, but is numerically of less importance than formerly. In Germany the 'little master' is also found, but the tendency to substitute a time wage for piecework rates is being in the main successfully counteracted by the solid opposition of the labour unions and also by the diffusion of electrical energy among the home workers, by which means the necessity of concentrating in factories in order to obtain the benefit of modern mechanical devices is obviated. In general the tendency is for the increased cost of working appliances and the internal economies of a factory where subdivision of occupations has free scope to hasten the advent of a factory type of industrial organisation pure and simple.

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5. *Trade Unionism in the Tinplate Industry. By* J. H. JONES, *M.A.*

The first association of employees in the tinplate industry was formed during the period of rapid expansion 1870–73. In 1873 workmen demanded the uniformity of wages at increased rates, but the time was ill-chosen. Uniformity was obtained in the following year, but in the majority of cases at reduced rates. There is no evidence of a continuous association before 1887, but there appears to have been a number of temporary combinations. The first association consisted of workers in the iron forges, tinplate rolling-mills, and the finishing departments. Between 1883 and 1886 steel displaced iron as the raw material for tinplates, and a cleavage followed of the steel-workers and tinplate makers. The steel-workers formed an independent association.

The union from 1887–98 was one of tinplate millmen and workers in the finishing departments. It was merely a wage-protective association, and its energies were directed mainly to (1) maintaining the wages rate agreed upon in 1874; (2) preventing the introduction of new machinery; (3) restricting the output.

Until the McKinley duty came into operation in 1891, U.S.A. was the chief buyer of tinplates from South Wales. The loss of this market caused severe depression for about six years, and it also resulted in a change in the character of the product. The trade in black plate (*i.e.*, untinned sheets) and sheet steel was developed. This pressed hardly on the tinhousemen, who fought against the working of black plate. Further to reduce cost of production, new machinery was introduced, which displaced some labour in the tinhouse and mechanised the labour of some of those not displaced. Thus there was a division of interests between millmen and tinhousemen. Disputes were generally over the conditions of work in the tinning mills, but the cost of them was borne mainly by those employed in the rolling mills. Other causes of dissatisfaction at this time were—

(*a*) The lack of funds to fight whenever necessary. Bad administration reduced the union to a penniless state and alienated a section of the men.

(*b*) The leaders granted reductions to individual employers, varying from 10 per cent. to 30 per cent. In this way they lost the confidence of the body of employers.

The wage-protective association collapsed in 1898.

The millmen were convinced that an association from which tinhousemen should be excluded was necessary. Some became members of the Steel Smelters' Association; the remainder, fearing to be the weaker section of a strong union, formed the independent 'Tin and Sheet Millmen's Association.'

The employees in the finishing departments joined either the National Union of Gasworkers and General Labourers, or the Dock, Wharf, Riverside, and General Workers' Union. Consequently in 1899 there were four workmen's associations connected with the trade, where previously there had been one. In the same year the Employers' Association, which was formed in 1873, was reformed, and a Conciliation Board established. This Board possessed no constitution, and there was no provision for cases of failure of conciliation. The first task of the Board was to establish a uniform rate of wages; and as the year was a very prosperous one the workers' associations found little difficulty in obtaining the '1874 list.' The agreement was renewed annually, and remains in force to-day, with but a few changes in rates paid to labourers whose tasks have varied slightly in difficulty.

To facilitate collective bargaining, the 'Tinplate and Sheet Millworkers' Wages and Disputes Board' was formed in 1901. This Board consisted of three representatives from each of the workmen's societies. All grievances of the men were to be submitted to the Disputes Board, and through the Board to the Conciliation

Board. The representatives on the Disputes Board were also the delegates on the Conciliation Board.

For two years the Disputes Board appeared to work satisfactorily; but in 1903 there was some friction, and again the diversity of interests of millmen and tinhousemen was made evident. The employers and the workmen failed to agree on a question affecting millmen. The masters wished to submit the dispute to arbitration, but to this the millmen (who were in a position to strike with fair prospect of success) were strongly opposed. The representatives of the finishing departments, who were not directly affected, naturally favoured arbitration, and the Disputes Board fell in with the wishes of the employers.

The Board of Trade appointed an arbitrator, and the case ended in a victory for the employers.

Further, in the following year, the Disputes Board decided to enter a test case (relating to the 'custom' of the trade) for trial in the High Court of Justice, the cost to be shared by the four associations connected with the Board. Three of the associations withdrew, and the Steel Smelters' Union was left to fight without financial assistance. The Steel Smelters' Union then resigned from the Disputes Board, which was consequently dissolved. The causes of the failure of this method of collective bargaining may be summed up as follows:—

(1) Matters concerning the finishing departments demanded the attendance of millmen (and *vice versa*), although they were not directly affected by the results and did not contribute to the discussion. Consequently, there was considerable waste of time.

(2) Voting power did not vary with the interests at stake—*e.g.*, millmen voted on questions affecting the finishing department. There was thus a lack of responsibility: one department would generally vote in favour of arbitration on a question affecting the other branch; they had nothing to lose by failure and everything to gain by avoiding a strike.

(3) A list of claims was presented to the Conciliation Board by each department. If the claims of one department, being just in the opinion of the employers, were granted by them, the concessions were made by the representatives of the other department the grounds for concessions to that department, irrespective of the nature of the claims. Thus, often the discussion did not turn on the justice of the demands by a particular section.

Since the Disputes Board was dissolved, the employers have met the workmen in two annual conferences—at one the millmen are represented, at the other the workers in the finishing departments. Wages agreements are made for one year, and agreements made with any section are operative 'from the date upon which an arrangement is completed with the other sections of the trade.'

TUESDAY, SEPTEMBER 8.

Joint Meeting with the Agricultural Sub-Section.

The following Papers were read:—

1. *Social Aspects of Agricultural Co-operation.* *By* J. GRAHAM BROOKS, *M.A.*

The social reactions of this form of co-operation are illustrated by (*a*) the lengthening of the labour-time during the year, and by the greater variety of things grown and by-products created—thus helping in the problem of unemployment; (*b*) the putting of the whole farming class to school; elementary science in many forms must be applied every day in the week; (*c*) helping to overcome the distrust of the well-equipped and competent man. This new confidence in the trained man is already beginning to show itself in the political field. It is actually producing a better type of clergyman and schoolmaster. (*d*) It is not only unifying interests, but is destroying the theory of necessary class conflicts, as presented by extreme Socialists; (*e*) it is throwing new light on the whole question of land-ownership and the social relations of this issue; (*f*) it has brought to the front the whole body of human and social interests, in such a way that they can now be dealt with far more safely; as illustrated by the various forms of insurance, and the popularising of higher sanitary standards for the house and school.

2. *The Psychological Aspect of Agrarian Reform in Ireland.* *By* Moritz Julius Bonn, *Ph.D.*

During the last twenty-seven years a thoroughgoing agrarian reform has taken place in Ireland. A radical system of fixing rents was created and supplemented by a very effective machinery for converting tenants into peasant proprietors. Have these reforms effected any of the great changes expected in Irish life?

(*a*) A statistical inquiry to-day shows a certain amount of progress. Irish live-stock, for example, has somewhat increased in numbers.

(*b*) Irish agriculture, as contrasted with pastoral industries, shows a steady decline.

(*c*) The development of live-stock and agriculture is practically the same in those districts where purchase of holdings has been carried out on a large scale as in those where it has scarcely taken place. The period 1881–1896, when prices were bad and reform was only started, does not differ very much in results from the period 1896–1907, when depression was slowly ceasing and reform was fairly advanced.

(*d*) The character of Irish farming as mainly a pastoral industry has been mentioned. Though tillage and mixed farming are considered profitable by experts, the change in ownership has not induced people to change the ways of production.

(*e*) Agrarian reform has brought about a considerable remission of the people's burdens. The income thus made available has been spent on a general rise of the standard of living. It has not been made an excuse for diminishing efforts in production, inasmuch as the country's agricultural output has not decreased. The energy of the people has not been sapped by it; but, on the other hand, there is no evidence that the great chances now within the grasp of the Irish farmer have had much influence on his qualities as a producer.

3. *The Productivity of English Agriculturists.* *By* Professor James Wilson, *M.A.*, *B.Sc.*

In 1696 Gregory King estimated the population of England and Wales at 5,500,000, and the areas under crop and pasture at 9,000,000 and 12,000,000 acres. Assuming that from 70 to 80 per cent. of the population was engaged in agriculture, and that a fourth of that number was operative as agriculturists, then there were about 1,000,000 agriculturists—farmers and workmen and their elder children—in the country.

King's estimates of crop and pasture were too high. Allowing for that, there were about eight acres of arable land and ten acres of pasture and meadow to each agriculturist.

Reducing all the grain to wheat, and remembering that the bulk of the arable land carried a crop only two years in three, and the rest of it only four or five years in eight or ten, then the average annual yield was not more than 8 bushels an acre.

In the same way, reducing all the pasture and meadow to milk, and remembering that a cow gave only from 200 to 300 gallons a year, and that, even though assisted by straw from the tillage land, three acres of meadow and pasture, unimproved as they were, would barely maintain her, then the annual yield of milk from an acre of meadow and pasture combined was not more than 80 gallons, Thus, from his eight acres of arable land and ten acres of pasture and meadow the English agriculturist of two hundred years ago produced about 64 bushels of wheat and 800 gallons of milk. His successor to-day works on the average about 13·64 acres of tillage and 15·63 of pasture and meadow, and from these he produces not less than 400 bushels of wheat and 4,000 gallons of milk.

On well-organised, fully capitalised, and well-managed farms such as are commonest in the east of England the productivity of the agriculturist is still higher—probably not less than 50 per cent. higher.

Taking the average: since the agriculturist of to-day produces four or five times as much from an acre, and works 30 acres instead of 20, he is equal to six or eight of his predecessors of two hundred years ago. At the best: since he produces five or six times as much an acre and works from 40 to 50 acres instead of 20, he is equal to over twelve of his predecessors.

This change has been brought about by improvements, chiefly in agricultural knowledge and methods, in organisation, and in machinery and transport.

The above has a bearing upon the following questions, among others: rural migration and depopulation, large and small holdings, agricultural education and organisation.

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4. *Economic and Statistical Investigation in Agriculture.* *By* W. G. S. Adams, *M.A.*

Some developments in agricultural statistics and economics were considered, and a plea made for their study and investigation at the universities of the United Kingdom.

WEDNESDAY, SEPTEMBER 9.

Discussion on Instruction in Universities as a Preparation for Commerce and Business Life.

SUB-SECTION OF AGRICULTURE.

Chairman—Right Hon. Sir Horace Plunkett, K.C.V.O., F.R.S.

THURSDAY, SEPTEMBER 3.

The Chairman delivered the following Address:—

Science and the Problem of Rural Life.

The Aim of the Address.

We have only to glance at the list of papers on our programme and of their authors to realise that our papers need be neither dull nor unimportant. It is true that our official title, 'Sub-Section "Agriculture" of Section "Economic Science and Statistics,"' is not inspiring. Even practical agriculturists may not see here much more than a place where the talk, if it be a little above our bucolic heads, will at least be concerned mainly with our business. Yet I am sanguine enough to hope that from the growing—if somewhat belated—recognition of our subject there arises the prospect of a notable contribution by the British Association to a neglected side of human progress.

In future years this Chair will be more properly filled by one competent to survey and appreciate, theoretically and practically, the past year's additions to knowledge within the province of our inquiries. But the Council have decided that this opening Address should be delivered, not by a man of science, but by a man of affairs. As such I shall address you; but, even in that capacity, I am conscious of serious limitations. My nearest approach to practical agriculture was a decade of cattle ranching in the Western States of America. There I learned much more about men than about cattle. I have been since then, for now some twenty years, in the public life of the country whose capital has been chosen for the honour and privilege of receiving the Association. These years have been spent mainly in organising voluntary effort among farmers, but, by the accident of politics, I was for over seven years responsible for the administration of the newly established Department of Agriculture and Technical Instruction for Ireland, an institution which has justified its existence, even if only, as public men have told us, since I left it. Its most important work consisted in the application of science to agriculture and the allied industries, mainly through education. My way of life has thus brought me into close touch with the conditions, human and material, which it will be the aim of our Sub-Section to improve.

These personal details, introduced in order to justify an Address upon the relations between a sphere of thought in which I am a comparative stranger and a sphere of action where I have no record of practical work, will also, I hope, serve to make clear the point of view from which I approach my subject. My definite purpose will be to establish the claim of agriculture to a wholly new position in the domain of science, and the claim of science to a more intelligent regard for those who, for the most part unconsciously, apply its teachings to their industry. The considerations to be submitted in support of this claim will be primarily neither scientific nor practical, but political. I need hardly say that I use the term in the only sense proper to the subject and the occasion; I speak as a citizen upon a problem—as I think, a neglected problem—affecting the well-being of that portion of the population which still follows the patriarchal calling, the oldest and most honourable field of human effort.

Past Neglect and Present Urgency of the Problem.

In some notes written two and a half years ago, at the request of an American statesman, upon the problem of rural life in the United States, I sought to account for the fact that a subject of such obvious and fundamental importance occupies so small a space in the public mind. 'Public opinion,' I wrote, 'is a town-made thing, and among Western nations the progress of civilisation has riveted men's thoughts upon the great centres of industry and commerce, where the most startling changes have taken place. The dweller in the modern city not unnaturally believes that the many and varied improvements recently effected in its conditions have fully counteracted the apprehended evils of concentration. He is confident that the rapid and cheap transit facilities which enable the industrial and commercial classes to live in ever-widening suburbs will realise the ideal of *rus in urbe*. What with improved sanitation and physical culture on the one hand and the multiplication of movements for intellectual advancement and social betterment on the other, the townsman of the future is expected to unite the physical health and longevity of the Bœotian with the mental superiority of the Athenian.' I have quoted this passage verbatim because, though I could paraphrase it, I could not condense it. For the same reason I ask leave to quote just one other brief passage in which I suggested an important omission in the reasoning upon which the townsman's optimism seemed to be based, and pointed a moral. 'It does not appear,' I wrote, 'to have been sufficiently considered how far the ethical and physical health of the modern city has been due to the constant influx of fresh blood from the country. At present the town makes an irresistible appeal to the spirit of enterprise, to the growing craving for excitement, to the desire to live where there is most life. But, sooner or later, if the balance of trade in this human traffic be not adjusted, the raw material, out of which urban society is made, will be seriously deteriorated; and the national degeneracy will be properly charged against those who failed to foresee the evil and treat the cause.'

Since these words were written the impression they reflect has been deepening in many minds, and the problem of rural life seems to be more than ever clamant for solution. The city, in the pride of its conscious fascinations, captures increasingly the best element of the country for its service, and this determination of blood to the head becomes more and more a threatening symptom in our national life. The consultant physicians are still the big men of the towns; some of them, it is true, are prescribing *urbs in rure* in place of the older ideal, *rus in urbe.* We hear much—we even see something—of the Garden City, but for any broad and philosophic treatment of the economic and social conditions of the open country we have still to wait.

Public Interest in Rural Life.

Although our problem has not yet received the proper attention at the hands of the sciences, its urgency is growing in the public mind and stirring the centres of government. If the British Association were to take action upon my appeal, they would be responding to the call of an awakened civic conscience. Physical degeneracy and the harassing prospect of unemployment in the towns—a prospect that soon every nation will have a huge derelict population, not merely unemployed but unemployable—have forced the problem of rural life over the threshold—aye, into the very forefront of practical politics.

The King's Speech at the opening of the present Parliament foreshadowed legislation 'by which a larger number of the population may be attracted to and retained on the land,' and measures framed upon an interesting diversity of principle have marked the stage of economic thought reached by our public life. Already President Roosevelt had, in more than one Annual Message to Congress, urged the necessity of improving, by every available means, the condition of that section (estimated by him to be nearly one half) of the population who 'devote their energies to growing things from the soil.' Nor has the great advocate and exponent of the strenuous life been content to wait until the play of political forces had produced a situation where the national problem he was determined to elucidate could be treated on its merits. Within the last month he has appointed a small Commission combining ideally in its five members the sciences most closely related to agriculture, rural education, the organisation of voluntary effort in social service, the highest kind of economic journalism, and that rare quality of administrative capacity that understands the limits of the respective spheres of State assistance and private initiative in practical affairs. The Commission are to survey the whole field of rural social economy; to review the existing agencies, voluntary and official, available for its betterment; and to suggest what action may legitimately be taken by the Government for the co-ordination of their several activities. They are to report to the President in time to enable him, while in office, to send a Special Message to Congress. If President Roosevelt adds to his stupendous policy for the conservation of the natural resources of the United States a scheme for developing those latent resources which it is the highest statesmanship to discover in the mind and character of the society of his day, it will be a fit ending to a great administration.

The real significance of this new departure—the definite governmental recognition that rural progress is a matter of national concern—is to be found in the circumstances of the country to which it relates. My own studies of the problem have been made chiefly in Ireland, Great Britain, and North America. To us Irish the problem is obviously one of paramount importance: its neglect means national decay. In Great Britain, although the neglect may be more easily explained and excused, it should, in my judgment, now be repaired. But in the United States, where, speaking generally, there is neither agricultural depression nor rural depopulation, it is doubtful whether any less far-seeing statesman than President

Roosevelt would have recognised the existence of the problem, much less have insisted upon its urgency. In my view the wide dissimilarity in the external conditions here and in the United States should bring into strong relief the human factor of the problem. It is the part of the statesman and the philosopher to see that this factor, neglected by the specialist, is given its proper place.

The British Association and Rural Life.

I pass now from the region of high politics, where national problems must be placed in their true perspective in order that their relative importance may be determined, and turn to the bearing of the sciences, within the scope of the British Association, upon the problems of rural life. And here let me say emphatically that while I speak as a politician, because I am discussing a vitally important national issue which politics will ultimately decide, the cause I have at heart is the enhancement of the influence of science upon the affairs of State.

Now this influence of the British Association must, it seems to me, depend, not upon its highest achievements in the region of pure science, but upon the degree in which it establishes and maintains a mutually helpful relationship between science and productive effort. To the man in the country lane, even more than to the man in the street, science unapplied is soul without body—only less negligible than the more common phenomenon of body without soul. And if there be nothing sordid in the suggestion, may I point out that until the coming of the ideal state those who devote their lives to research must be maintained by those who make use of, and profit by, their discoveries? It is no longer necessary for the master of great thoughts to find a patron before he can get a public; but it were well to remember that while Demos pays Literature and Art for instruction and amusement, he exacts of Science an increase of wealth and comfort. In the town these conditions are fulfilled; in the country they have yet to be supplied.

The Three Sides of Rural Life.

Those of us who are working upon the problem of rural life in Ireland adopt a rough formula to indicate the threefold character of the constructive work which is needed for a complete solution. *Better farming, better business, better living,* we say, covers the ground. For farming clearly has three sides: the first dealing with the cultivation of the soil, the breeding and feeding of stock; the second, with the principles of farm management, its finance, and the economy of agricultural production and distribution; and the third, with the social life of the agricultural classes. In each of these three divisions we can have most helpful relations with the sciences: in the first, with the natural sciences; in the second and third, with economic, in which I include social, science; and in all three, with educational science. I now proceed to consider the three departments of rural life and work, and the demands they make on the several sciences and the sections embracing them.

(1) *The Natural Sciences and Agriculture.*

In the first of my three divisions—better farming—we have to consider the relations between science and practice in agriculture so far as they are affected by the work of the British Association generally and of our Sub-Section in particular. Let me call you back seventy years to the meeting of 1838, when the British Association obtained from Liebig his epoch-making report upon the application of chemistry to agriculture. At approximately the same time the Rothamsted experiments—the one continuous organisation for the advancement of agricultural knowledge the United Kingdom has to show, and the largest individual contribution to such knowledge—were initiated. These two events are evidence of the comparatively larger part agriculture played in national life and thought then than it does now. Up to this time it is doubtful if agriculture had made any substantial advance since the time of the Romans. The work of Liebig, Gilbert, and Lawes in one direction only—the feeding of the plant—has resulted in the use of fertilisers drawn from either fossil deposits or manufacturing waste-products that has brought up the yield of our crops to an entirely new level. Lawes reports that the average crop of wheat in his district at the beginning of his experiments was about twenty bushels per acre; to-day it is over thirty bushels. Of course it is not fertilisers only that have done this. Scientific method has also been applied to the machines which cultivate the soil, to the breeds of plants growing there, and to the eradication of the diseases from which they suffer.

I do not suggest that agriculture has not shared in the benefits with which science, physical and social, has richly endowed the whole field of industrial effort, urban and rural. But when all is said, there is surely a marked disparity between the attention given to urban and to rural affairs by those engaged in the application of science to the material and social advancement of mankind. In the sphere of the physical sciences a great gulf no doubt separates the agriculture of Virgil from that of Sir John Lawes; but how insignificant it is beside the ocean of knowledge which stretches between Archimedes and Lord Kelvin.

It is not, however, with the knowledge itself, of the nature and amount of which I have but the haziest conception, that I am here concerned. I am quite certain that the British Association—I might say this audience—is in possession of knowledge which, if applied, would enormously add to the agricultural wealth of all countries, especially my own. The work of the moment, by far the most important work of our Sub-Section, relates to the diffusion of this knowledge. This end is to be attained in two ways—by an improvement in the means of translating the research work of the field and laboratory into the workaday experience of the farmer and by a co-ordination of the work done for the advancement of the industry with that which seeks to improve the economic and social character of those who are making their living out of the soil. Deficient as is the provision for research in agriculture in this country, the working farmer is still very far from utilising all the knowledge which science has already put at his disposal. The intellectual apathy which the governing class displays towards the acquisition of new knowledge is reflected in the neglect the farmer shows in learning what has already been acquired. But, although I have every confidence in their source, I admit that these views are second-hand. I shall be more at home in the region of the other sciences which are concerned with the human as distinct from the material conditions.

(2) *Economic Science and the Business of Farming.*

Coming then to the second factor in our problem—as I have presented it—let us consider for a moment the business of farming in its relation to economic science. A story—founded, I have good reason to believe, on fact—will serve better than any arguments I could use to show the necessity of paying due regard to the commercial as well as to the technical aspects of agricultural problems. Some of Liebig's pupils, fresh from the laboratory and the world of abstract thought, set out to make a new conquest in the world of fact. They procured a fine tract of land in the Argentine, upon which they applied all the latest discoveries of agricultural chemistry. A large capital and a wealth of new knowledge were expended in restoring the fertility of the land, and the land, no doubt, responded to the treatment. But the money, without the science, would have sufficed to purchase fresh tracts of virgin soil; and thus, while the harvest of these uneconomic laboratory men brought credit to their mastery of scientific truth, it did not save their credit in the bank—and they were sold up.

From my own observation and experience I should say that farmers are more backward in their business than in their technical methods. I am convinced that there is no more important work at the moment than to stimulate economic thought in the country in order to give the rural population an intelligent interest in its own problems. My administrative experience on this point is pertinent. In the Irish Department, which was concerned with the advancement of rural life, it was our constant aim, while retaining central supervision, to delegate the administration of the local work more and more to local representative bodies.

What handicapped us and them most severely in comparison with similar bodies engaged upon similar work in other countries was the lack of business organisation among farmers. I have no hesitation in laying it down as a fundamental principle of agricultural development that organisation for business purposes is an essential condition of a demand for technical advice, and of a willingness and capacity to apply it. This brings me to what is, perhaps, the most important of all agencies in rural progress. I refer to agricultural co-operation.

It is in regard to the organisation of industry that the modern city has made its greatest advance as compared with the country. It should be remembered that the problem of rural life is a product of the industrial revolution which deprived the open country of all its economic activities, except the production of food for the sustenance of the urban population, and of raw material for its manufactures. This inevitably had a narrowing and depressing effect upon rural society. I know farming communities in the most fertile portions of the United States where it is the settled practice of the up-to-date *paterfamilias* to send his hopefuls to the city and keep the fool on the farm. In the economic changes consequent upon the industrial revolution the organisation of the commerce and industry of the towns proceeded apace. The circumstances of farm life did not lend themselves to any similar process. At the same time, the increased demand for agricultural produce in bulk of uniform quality urgently called for the organisation of farmers if they were to compete in the world-market. To supply such a need the co-operative system has been adopted by European farmers wherever education is so related to the life of a people that economic thought is developed. In these islands the work of organising farmers, of giving the country a co-operative system which is the counterpart of the joint-stock system of the towns, has to be left to agricultural organisation societies constituted for the special purpose of inducing farmers to do here what elsewhere they do spontaneously.

Now the point I wish to emphasise is that agricultural co-operation has a far higher aim, purpose, and justification than is to be found in the immediate and obvious business advantage of joint action in the purchase of requirements, sale of produce, mutual credit and insurance, and the well-known forms of combination for productive purposes. If the economists would realise that those who are organising farmers with the primary purpose of giving them some chance of placing rural life upon a permanent basis of comfort are in reality making for a much larger end, they would devote a little more attention to those who are engaged in this work, and who are in a position to give practical effect to any addition that they may make to the available supply of economic thought.

(3) *Social and Educational Science in Rural Life.*

I take now the third part of the threefold division of the social service under review, *better living*. There co-operation is as necessary as it is in the diffusion of technical knowledge. People who are brought together for mutual advantage in the business of their lives are easily induced to apply their organisation for purposes of mutual social and intellectual improvement. The complete reconstruction of the social life of rural communities is as urgent as the reorganisation of their business.

Before leaving agricultural co-operation, its primary purpose and incidental effects, I would like to say a word upon its bearing on the small holdings question. Everybody admits that agricultural co-operation is beneficial in inverse proportion to the economic standing of the farmer, and that the isolated small holder will have a very doubtful prospect to face. Yet neither in Great Britain, where small holdings are being multiplied, nor in Ireland, where the people are on the land, but where vast numbers of them have to be resettled on new holdings, has nearly sufficient thought been given to this aspect of the question. It is a matter of immense importance to consider whether the family should be the unit in our schemes for reconstituting our rural social economy, or whether it would not be sounder to treat communities as units; otherwise, no matter how we preach co-operation, it may not be practised. I cannot, of course, pursue the subject further, but I suggest to the economists that they would find here a rich field for research. I know what Ireland suffers from is the delusion that the solution of the rural problem is to be found in the magic words 'an economic holding.' What we should try to develop is an economic system and the economic man to work it.

There is one more factor in rural reconstruction which, though I have kept it to the last, is unquestionably the most important—that is, rural education. Here, again, a vast subject must be despatched with the fewest number of words which will suffice to indicate those of its aspects which bear upon our problem.

Up to a certain point the education of the rural school is, in its essence, identical with city education. The character of the child has to be built up and its mind stored with a certain number of necessary facts which nature curiously enables us to assimilate much more easily when they are of no use to us than when we want to apply them to practical life. But the point of divergence between town and country education appears to me to be reached when the course of study has regard to the mental outlook.

There are two human attributes to which the city appeals irresistibly, quite apart from the better opportunity it affords of material advancement—the gregarious instinct and the love of excitement. Improved locomotion and means for communicating thought from eye to eye and from ear to ear, the organisation of social functions in rural centres, and lectures illustrated by the moving life of the cinematograph—to take the latest addition to the mechanical aids to exposition—will all help. But their influence may be centripetal with some, centrifugal with others. No conceivable devices by which the country may gain some share of the enjoyment of the town can destroy the lure of the city. The farmer's calling is one of constant and unremitting toil. No process of evolution will evolve a cow which will consent to do without milking on Sunday. A modest standard of physical comfort, devoid of all expensive luxuries, must continue to be the lot of the tillers of the soil. The one way to offset the townward tendency is to revolutionise the mental outlook of the rural population, to concentrate it upon the open country.

How this is to be done it is for those who lead thought in educational science to say. All I can do is to define the need as I see it. We want two changes in the rural mind. The physical environment of the farmer is replete with interest to the followers of almost every branch of natural science. That interest must be communicated to the agricultural classes according to their capabilities. 'Nature study,' I believe, is the latest term of the pedagogues for the revelation of the simple natural processes; but to make those processes interesting to the child you must first make them interesting to the teacher. The second change in the outlook relates to the spiritual rather than to the utilitarian side of education. Somehow or other, that intimacy with and affection for Nature to which Wordsworth has given the highest expression must be engendered in the mind of rural youth. In this way only will the countryman come to realise the beauty of the life about him, as through the teaching of science he will come to realise its truth.

The Birth, Death, and Reincarnation of the Agricultural Sub-Section.

I have now described in broad outline the problem of rural life as it presents itself to my mind. I have drawn attention to, and tried to account for, the failure of public opinion to recognise the gravity of the conditions out of which the problem arises. Coming to the immediate concern of our Sub-Section, I have argued that it will require a co-relation of all the sciences embraced by the British Association to give even the hope of a satisfactory solution. I cannot conclude without pointing out the treatment our subject has received since the Association gave to it a distinctive—if a subordinate—position in its deliberations.

At Cambridge, four years ago, Dr. Somerville, in his inaugural Address, expressed the thanks of those present to the British Association 'for the encouragement and stimulus which are associated with the formation of an agricultural Sub-Section.' The gratitude in this case was for favours not to come. My distinguished predecessor, I can well imagine, saw in this union of science and practice, within the sphere of his life's work, an invitation to a veritable marriage feast. He had reason to hope that if, in the humble seat allotted to us, we acted well our part, the masters of the feast would have said to our Sub-Section, 'Friend, go up higher.'

How far that hope has been fulfilled may be best judged by the brief, uneventful history of our Sub-Section, which is easily told. The records show that after our birth, at an ancient seat of learning in 1904, we were put out to nurse in Section K—Botany. We do not appear to have survived the following winter, but our ghost seems to have haunted Section B—Chemistry—for the three succeeding years. After this unnatural treatment by the natural sciences we are to-day reincarnated and left on the doorstep of Section F, where I hope some humanised supplement to the separated milk of statistics will be found for our sustenance. I suppose if we get beyond a second childhood we shall be sent to school in Section L—Education. I shall then feel that my idols, Gilbert and Lawes, have been shattered; that Gilbert and Sullivan reign in their stead.

When I mastered the history of the Sub-Section over which I was to preside I thought it well before preparing my Address to seek advice from the members of the British Association who could speak with authority as to the position which I might claim for our subject in the future. I was dragged in two opposite directions. Some, fearing no doubt the fissiparous tendencies attributed to Irish public men by those who do not understand the catholicity of our sympathies, vehemently deprecated my suggesting the creation of yet another Section. Others, whose loyalty to the Association was only exceeded by their interest in agriculture, pressed upon me that the time had come for placing us in an independent position, where we could draw from and contribute to all the Sections as our growth demands. It may be said that agriculture is not a science, but neither is engineering. Indeed, I can find no reason why engineering should enjoy the dignity of a Section and agriculture be restricted to a Sub-Section, unless it is to be found in the subordination of rural to urban interests. I know well the inconvenience of what we in Ireland call a long weak family, but I thought the experiment of *solvitur ambulando* had been sufficiently tried upon the *corpus vile* of our Sub-Section.

In all the circumstances a new Section for Agriculture seems to be indicated. The public advantage of thus recognising the reality and urgency of the rural problem, the popular influence which the British Association would command by bringing the sciences to its solution, appear to me to outweigh objections based upon the ideals of symmetry and logical division in the central body to which our Sub-Section is so indeterminately attached.

The Appeal of Agriculture to Science.

Although the subject I have chosen for my Address is unquestionably of greater importance to Ireland than to any other portion of the Empire, I hope the arguments I have placed before you are of no insular character. At any rate the problem is not insular, it is co-extensive with our civilisation. And, speaking for the unscientific, I submit that it should not be hastily assumed that we whose life work compels us to have chief regard to material considerations and the country side of things fail in our appreciation of those who devote their life to pure science. I know in my own case how deeply impressed I was by the thought of a contemporary philosopher in closest touch with large affairs, which appears to me to strike a true, a hopeful, and, I may add, an extraordinarily interesting note. Mr. Arthur Balfour, one of your former Presidents, has recently suggested that familiarity with the truths, wholly apart from the physical enjoyment of the achievements of science, might constitute a new fact of happy augury for our modern civilisation. It might counteract tendencies through which preceding empires, after they had arrived at a stage very similar to that which we occupy to-day, hastened to their decline and fall. The most calamitous national downfall which history records—that of the Roman Empire—finds its commonest, if not its complete, explanation in the neglect of the country by the town. Is there not something analogous to this neglect in the modern Empire of Science? Whatever answer be made to this question, I feel that, in the interests of our national progress, I am justified in the appeal I make that, before modern civilisation goes too far down the road of the rural exodus, the British Association should take science and practice hand in hand and call it back.

The following Papers were then read:—

1. *Irish Soil Maps.* *By* Professor GRENVILLE COLE, *F.G.S.*

2. *Electricity in Agriculture.* *By* Sir OLIVER LODGE, *F.R.S.*

It has been found by large scale experiments on a farm near Evesham, as well as by other previous experimenters, that a discharge of positive electricity into the air above growing plants stimulates and increases their growth; especially when the sun is not too strong or the soil too dry. In this latter case it may over-stimulate them. The reason for this action of electricity requires investigation.

The experiments have been carried out by Mr. J. E. Newman and Mr. Lionel Lodge on the farm of Mr. R. Bomford, of Bevington Hall, Evesham, and at the nursery garden of Mr. G. R. Newman, at Bitton, near Bristol.

3. *Agricultural Education.* *By* J. R. CAMPBELL, *B.Sc.*

It is not perhaps well known that there was an agricultural school in Ireland as early as 1826. Those interested in this early venture will find an account of it in Thackeray's 'Irish Sketch-book.' The school was established by private subscription, and was self-supporting for nearly twenty-five years. In 1838 the Commissioners of National Education began their system of agricultural instruction, which they continued up to the creation of the Department of Agriculture and Technical Instruction in 1900. The Commissioners started by giving lectures on agriculture to teachers in training. It was as a demonstration farm in connection with such lessons that the present Albert Agricultural College, Glasnevin, was founded in the same year, 1838. The lectures were intended to qualify elementary schoolmasters to give instruction in agricultural science, while the college farm and its gardens were used to teach them to cultivate educational gardens and small farms attached to national schools. Later, about twenty agricultural schools were established in various parts of the country by the Commissioners, at which provision was made for resident students. These served at the same time as training centres for pupil-teachers and headmasters living in the vicinity. The Commissioners aided other schools established by private influence, and offered inducements to Poor Law Guardians to provide agricultural education in workhouse schools.

In 1900, when the Department of Agriculture was established and charged with the duty of providing agricultural education in Ireland, all that remained of the provision made by the Commissioners were two institutions—one the Albert Agricultural College, Glasnevin, and the other the Munster Institute, Cork. After a study of the situation in 1900, the Department of Agriculture and Technical Instruction decided on the following policy:—

1. To provide at one central institution the highest form of technical education for the training of men who are to become teachers and specialists in agriculture. This has been done at the Royal College of Science in connection with the farm and college at Glasnevin.

2. To provide at least one high-class agricultural college which would form a stepping-stone to men desirous of entering the Royal College of Science, as well

as men, the sons of well-to-do farmers, who wish for an education to enable them to manage their own farms, and men who desire to become creamery managers, or who wish to have a special training to fit them as horticultural or poultry experts, stewards, land agents, or other occupations in connection with agriculture. This has been done at the Albert Agricultural College, Glasnevin.

3. To provide provincial institutions at which young men who can be spared from the farm for one year can be taken in as apprentices, taught agriculture, both practical and technical, at a fee proportionate to their means. This work, which had to be delayed until teachers were trained, is now in progress at three such institutions, and the provision of others is in contemplation.

4. To provide winter schools of agriculture where the sons of farmers could obtain technical training at small expense during the winter months, when they can best be spared from farm-work. About thirty such schools were in existence last winter in twelve counties where progress had previously been made with itinerant instruction.

5. To provide one central higher institution for the training of women in the domestic economy of the farmhouse, and in work which falls to the lot of women to perform in connection with the farmyard, as, for example, dairying and poultry-keeping. This provision has been made at the Munster Institute, Cork.

6. To provide for young women education in domestic economy and farmyard lore at residential and day schools. This has been done at eight institutions, while the equipment of others is under consideration.

7. To provide in each county, by a system of itinerant instruction in agriculture, horticulture, dairying, poultry-keeping, and bee-keeping, instruction and advice for farmers and their wives, sons, and daughters who cannot avail themselves of other means of acquiring information.

8. Finally, in the application of all forms of State aid to make the schemes of an educational character, and not to allow such aid to assume the nature of a direct subsidy.

Thus the Department have laid the basis of a graduated system of agricultural education by means of which the youth who is inspired by the work of the itinerant instructor may be able to obtain education in the local winter school of agriculture, from which he may graduate to the provincial agricultural school, thence to the Albert Agricultural College, or the Royal College of Science, according to his circumstances and his education.

Prior to about 1890 agricultural education in Great Britain was maintained for the most part out of private funds, and was directed by leading agriculturists. Since that date it has been supported by the State, and has claimed more attention from recognised educational authorities.

In Scotland this form of State aid is administered by the educational authority, as was formerly the case in Ireland, while in England it is administered by the agricultural authority, as is now the case in this country.

Thus there have been three sets of administrators engaged on this important work, viz. (1) agriculturists themselves; (2) the State education authority; and (3) the State agricultural authority.

The author referred to the methods and procedure, as well as to the results obtained by these three bodies, and deduced therefrom the lines which future action should follow. Special reference was made to proposals for instruction to boys attending elementary schools.

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4. *Agricultural Education for Business and for Knowledge.* *By* Dr. CARROLL DUNHAM.

FRIDAY, SEPTEMBER 4.

The following Papers were read:—

1. *Discussion on Breeding and the Relation of Modern Theories of Heredity to the Problems of the Stock Raiser.*

(i) *The Application of the Mendelian Theory to Practical Problems.* *By* Professor W. Bateson, *F.R.S.*

(ii) *Experimental Breeding Farms.* *By* W. Heape, *F.R.S.*

(iii) *Mendelism and the Elucidation of Live-stock History.* *By* Professor J. Wilson.

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2. *Some Irish Experiments on Warble-flies.*
By Professor Geo. H. Carpenter, *B.Sc., M.R.I.A.*

For the past four years experiments have been carried on by the Irish Department of Agriculture as to the life-history of the warble-flies and the effect of the commonly accepted means for checking their attacks on cattle. In January of this year a first report of these experiments was published in the Department 'Journal' by the writer and Mr. J. W. Steen. The experiments were for the most part carried on at Ballyhaise, co. Cavan.

The most important practical result of the experiments has been to show the uselessness of dressing cattle either with carbolic 'dip,' oil and tar 'smear,' or paraffin emulsion with the object of preventing egg-laying. For example, six yearlings were smeared all over every day from May till September 1906. In 1907 they showed warbles averaging over 30 per beast. Four calves sprayed all over daily during the same period showed an average of 15 warbles per beast the next spring. The average number of warbles on untreated animals at the same time was 31 for heifers and 11 for calves.

In the spring of 1907 a systematic squeezing-out and destruction of maggots was therefore set on foot: 2,090 maggots were obtained from 194 head of cattle on the Ballyhaise farm, an average of nearly 11 per head. The good effect of this operation has been strikingly shown in the spring of the present year, when from 166 head of cattle only 694 maggots were obtained—an average of 4·2. Equally instructive is the fact that five cows grazed on the outskirts of the farm, and therefore open to the attacks of flies from the surrounding country, had an average of 16 warbles per beast, while 94 cows grazed near the centre of the farm had an average of only 3 warbles per beast.

Observations show that the flies lay their eggs usually on the legs, very rarely on the backs of the cattle. During the summer of 1906 six calves were muzzled by day and tied up between stakes at night so as to prevent them from licking themselves. All but one of these had warbles in the spring of 1907, whence it was surmised that the maggots may gain entrance through the skin, and not, as is now generally believed to be the case, through the mouth. During the summer of 1907 two calves were muzzled and tied, with additional precautions. These were the only two calves on the farm that as yearlings are entirely free from warbles this spring (1908). It is likely, therefore, that the protection from licking in the 1906 experiments was in some way incomplete. During the present summer six calves are being again treated in this way, and it is hoped that the method of entrance by the mouth will thus be conclusively tested.

Hypoderma bovis seems to be far commoner in Ireland than *H. lineata.* In both species the interval between the emergence of the maggot from the beast's skin and the appearance of the fly is about seven weeks.

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3. *Barley Growing and Selection in Ireland.* *By* HERBERT HUNTER, *B.Sc.*

After dealing with the manner of origin of many of the varieties of cereals which are to-day in cultivation and the methods of improvement adopted by early workers, such as Colonel Le Couteur and Patrick Sherriff, the author proceeded to describe some of the leading varieties of barley in use in Ireland to-day.

Incidentally some recent experiments in the cultivation of this cereal carried out by the Department of Agriculture in Ireland were referred to, and the main conclusions of these investigations dealt with. The special requirements of barley for malting purposes were described, together with the effect of pure and mixed seed on the quality of the produce. The author then proceeded to enumerate the various methods adopted for the production of pure-seed supplies, and showed by actual examples from experimental single-ear cultivations of Old Irish, Chevallier, and Archer varieties the existence of many closely related strains of the same variety. The constancy of the characteristics of each type was then dealt with, and their adverse influence on a pure-seed supply demonstrated.

The existence of 'quality' in barley as a specific character was pointed out, and the possible lines of improvement in this direction indicated.

As good 'quality' and high yield do not appear to be coexistent in present-day varieties, selection of the forms possessing these characteristics in the highest degree must eventually lead to hybridisation. In all cases, however, selection of varieties with demonstrated characteristics must precede hybridisation, as this process results in forms, new rather in the combination of definite characters than in the production of intensified ones.

It was pointed out that, whether dealing with hybrids or pure natural varieties, it is desirable to propagate seed for commercial purposes from single grains or ears, as this method results in seed possessing a minimum amount of variation in any direction, and is on that account more valuable commercially.

MONDAY, SEPTEMBER 7.

The following Papers were read:—

1. *Small Holdings: Some Considerations on their Successful Establishment.* *By* Mrs. L. WILKINS.

The author discussed some general principles which have emerged during work on the subject in England.

The present interest in the Irish land question, following on the Report of the Commission on Congestion, leads one to think of the whole question in connection with Ireland. The circumstances of the two countries are so different that the application of these general principles is fundamentally affected.

Small holdings originally were not established but were a natural outcome of existing conditions. The small man created them by means of his own labour while earning his maintenance.

At the present day he has, as a rule, to have capital to pay for the creation of his holding, except in those cases where farm land goes into market gardening or fruit growing. The difficulty he experiences in obtaining land in England is not through dearth of land, but through want of organisation; for the land in the market is mostly in large areas beyond the means of the individual.

Necessity of Legislation to remedy this: Consideration of facts with which legislation has to deal in the two countries. The fundamental point is: are the people entirely dependent on the land for a living?

In England, it being a manufacturing nation, they are not exclusively so; in Ireland, speaking generally, they are.

The influence of this on the nature of the small holdings: in England it is possible to get a living off a small area of poor land, (i) by working it in connection with some industrial occupation; (ii) by having a supply of good local markets in the large industrial towns. Also the fact of not being entirely dependent on the land makes it more difficult to induce the small holder to adopt newer methods of cultivation, &c.

In Ireland, on the other hand, the land must practically be made sufficient for all. This can only be done by insisting on improved methods of intensive cultivation, co-operation, &c.

In England legislation such as the Small Holdings Act of 1907 is practically designed to assist people to get on to the land at their own expense. The process will afterwards be a form of natural evolution.

In Ireland, the process must be more in the nature of a revolution in agricultural methods; the people are already on the land: legislation must be directed towards helping them to work it to the best advantage.

Consider establishment of holdings more in detail.

The fundamental conditions necessary for success in England are *one or other* of the following:—

Good land, favourable climate, good markets, common rights, opportunities for labour as an adjunct.

The importance of the *size* of holdings under various conditions.

The sizes found necessary in different parts of England:—

In the Isle of Axholme:—

Two acres for a labourer in regular work;
Five to ten acres for a man doing job work;
Ten to twenty acres for an entire living.

In the market gardening districts of Bedfordshire:—

Half acre for a man in regular work;
Six to ten acres for a living.

In cheese-making districts on grass land—twenty to thirty acres.

Summary of argument: That the successful establishment of small holdings depends very largely on the regard paid to local details. But this cannot be done on far-seeing or economic lines until you have got these details located in the exact position they hold in the economy of the nation at large.

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2. *The Small Holdings Problem.* *By* CHRISTOPHER TURNER.

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3. *The Management of Small Holdings.* *By* F. IMPEY.

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4. *Letters from Small Holders.* *By* W. BEACH THOMAS.

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5. *The Economic Importance of judicious Tree Planting for Shelter by Farmers.* *By* J. SCOTT KERR.

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6. *A Method of Registering the Colours of Animals.* *By* Major BARRETT HAMILTON.

TUESDAY, SEPTEMBER 8.

Joint Meeting with Section F.—See p. 794.

Section G.—ENGINEERING.

President of the Section—Dugald Clerk, F.R.S., M.Inst.C.E.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address:—

At the middle of the last century the steam engine had attained to a high degree of perfection. Its development was, it is true, incomplete, but it had been successfully applied to all the great duties of the mine, the waterworks, the factory, the railway, and the steamship. The engines were mechanically excellent; the fuel economy was good, and they were built in units of thousands of horse-power. Steam power, in fact, was revolutionising the whole of the social and industrial conditions of the globe. Notwithstanding this great material and engineering success, the world was in complete darkness as to the connection between steam motive-power and heat. It was seen that motive power of almost any magnitude could be obtained by the agency of heat; but how it was obtained and how much power was connected with a given quantity of heat was quite unknown. The fuel consumptions of existing engines were known, and certain modes of improving economy were evident, and engineers were busily engaged in testing these modes by the slow but sure methods of invention, design, construction, and operation in practical work; but in this they had but little aid from pure science.

The science of thermodynamics did not yet exist.

New light was dawning, however, which gradually illumined the whole world of pure science and engineering practice.

Men of the first rank in intellect—Newton, Cavendish, Rumford, Young and Davy—had long before expressed the opinion that heat was not material in its nature, but was a mode of motion; but their opinions, although to some extent supported by experiment, made little impression upon the scientific world, and in 1850 we still find the most distinguished physicists adhering to the 'caloric' or material theory of heat.

The great change, from the errors of the old theories to the truth of the new, was due to the work of Joule, Thomson, and Rankine in Great Britain, and of Carnot, Meyer, Clausius, Helmholtz, and Hirn on the Continent. The story begins with the work of Carnot in 1824, who published in Paris in that year a pamphlet entitled 'Reflections upon the Motive Power of Heat.' He was attracted by the problem of the steam engine and the air engine. He saw that heat and motive power were connected in some manner, and he endeavoured to settle in a quantitative way the limits of that connection by the invention of an ideal series of operations by means of which the greatest conceivable amount of mechanical power may be obtained from a given quantity of heat under given circumstances. For the purpose of his demonstration he assumes only two things: (1) That if heat be added to any body under standard conditions of temperature, pressure, and volume, and the body be carried through any series of mechanical processes, returning ultimately to the standard condition of temperature, pressure, and volume, then the quantity of heat added to the body is the same as that which has been discharged from it; (2) No process can exist whereby a given mechanical energy can increase its own quantity. On these indisputable assumptions he bases his ideal cycle, which consists of four simple and easily imagined operations, occurring within a cylinder behind a piston, so arranged that during the cycle work can be done by the working fluid upon the piston or work done by the piston on the working fluid.

First Operation.—The given volume of the working fluid is to be imagined as confined at its highest temperature and pressure behind the piston, and heat is to be added to keep the temperature constant, while the fluid expands, moving the piston and doing work upon it.

Second Operation.—The supply of heat is cut off, and the working fluid expands also during work on the piston, while its temperature falls to the lowest point and its volume increases to its maximum.

Third Operation.—The piston returns, compressing the working fluid, but allowing the heat of compression to escape, so that the temperature remains during the operation at its lowest point.

Fourth Operation.—The piston compresses the working fluid, without allowing any loss of heat, to such an extent that the temperature rises again to its highest point, and the working fluid exists at the end of this operation at the same volume, pressure, and temperature as at the beginning.

This assumed series of operations would give a certain available work area, the indicated power of the engine, inasmuch as the work done by the working fluid would be greater than that done upon it. If however it be assumed that in all the operations the direction of motion of the piston be reversed, then compression without loss of heat would take place in the second operation; further compression, but with sufficient heat loss to keep temperature constant, would occur on the first operation; the fourth operation would follow with expansion, and the third operation would conclude also with expansion. The engine would be reversed by beginning with the second operation, moving the piston backwards in the order second, first, fourth, third. Carnot shows that this reverse operation would be performed by exactly the same amount of work as was given out by the direct operation, and that an amount of heat would be returned at the higher temperature equal to that which was added in the first case.

An engine which fulfils these conditions, Carnot states, will give the greatest amount of work which can be obtained from a given quantity of heat falling through a given temperature range. And it is evident that this must be so, because, if we assume the existence of any engine under the same conditions giving a greater amount of work from the same heat, then that engine could drive a Carnot engine in the reverse direction in such proportion as to return to the higher temperature a greater amount of heat than it abstracted, and so mechanical energy could be obtained without any heat fall whatever. This marvellous demonstration is obviously independent of the nature of the working fluid; it applies equally to all working substances, whether solid, liquid, or gaseous, whether physical state changes or not. It at once gives a standard of the limit of mechanical power which could possibly be obtained from a given amount of heat and a given temperature fall.

The Carnot cycle operations, as here given, are applicable either to the material or to the dynamical theory of heat; but Carnot originally stated that the whole of the heat added in the first operation was to be discharged in the third. Under the material or caloric theory, work was supposed to be done by the fact of fall in temperature. Naturally, as the heat was material it could not be destroyed or changed into mechanical energy. The production of mechanical energy was supposed to be incidental to the fall of temperature, much in the same way as mechanical energy was produced by the fall of water-level, and this analogy is used throughout Carnot's work of 1824.

Carnot thus succeeded in proposing a standard of efficiency which was applicable to any heat engine, whatever the working fluid and whatever the operative cycle. By his method a limit could be set, fixing the maximum of mechanical energy to be obtained from a given heat quantity and a given temperature range. To reduce this to numerical values it was necessary, however, to experiment on any one working fluid within the desired temperature range in order to determine the work area in its relation to heat quantity and temperature fall. Carnot's writings show that he intended to make such observations; and, had he succeeded, thermodynamics would have become a science at an early date. Carnot's death, however, in 1832, at the sadly early age of thirty-six years, prevented this development.

The name of Sadi Carnot will always be remembered by mankind as the founder of one branch of the thermodynamics of the heat engine.

His work remained practically without notice for thirteen years after his death, when, fortunately, it attracted the attention of William Thomson during his attendance at the Laboratory of Regnault in the year 1845. Thomson was then twenty-one years of age, and had already attained a considerable scientific reputation. He took up the study of Carnot's work with enthusiasm. He became Professor of Natural Philosophy in the University of Glasgow in 1846, and in 1848 he read a paper before the Cambridge Philosophical Society 'On an Absolute Thermometric Scale founded on Carnot's Theory of the Motive Power of Heat and calculated from Regnault's Observations.' Like Carnot, Thomson accepted the 'material' or 'caloric' theory of the nature of heat, although, like Carnot also, he had doubts as to its truth. Assuming its truth, however, he carried Carnot's reasoning much further, and deduced from the Carnot cycle a thermometric scale which was absolute in the sense that it defined the idea of temperature independently of the properties of any particular body.

It is very difficult to carry one's mind back to the material theory of heat, but it is necessary to do so in order to appreciate the rigid accuracy of the reasoning of both Carnot and Thomson; and it is especially desirable to do so in order to understand the great step made in this paper. According to the 'caloric' theory, heat was supposed to be a subtle elastic fluid which permeated the pores of bodies and filled the interstices between the molecules of matter. The fundamental quality imagined of this caloric or heat fluid was that of indestructibility and uncreatability by any humanly controlled process. Bodies became warmer when caloric was added to them, and grew colder as it left them. Caloric, however, might be added to a body without heating it. In this case the heat was called 'latent,' and the state of the body changed from solid to liquid or from liquid to vapour or gas.

Caloric, too, was required in greater quantities for some substances than others in order to warm the body equally. The capacity for caloric was thus greater in some bodies than in others.

If any particular body were heated without change of state it was hotter; that is, its temperature rose when the quantity of caloric present was increased. It was not difficult to define equality of temperature. This was defined by a constant condition when brought into contact. But it was very difficult indeed to define temperature on any rational scale.

To the acute and brilliant intellect of William Thomson it became apparent that he had in the Carnot cycle a powerful instrument capable of widely general use, apart altogether from the theory of heat engines; and he here uses it in a most skilful way to give definiteness and universal application to the idea of temperature, as Professor Larmor states, 'elevating the idea of temperature from a mere featureless record or comparison of thermometers into a general principle of physical nature.'

Thomson accordingly defines equal differences of temperature in terms of the reversible or Carnot engine.

Equal temperature differences are to be differences between the temperatures of the source of heat and the refrigerator, when the proportion of work produced from a given quantity of heat is the same. Thermometers graduated in degrees calculated in this way could naturally be treated as instruments based on definite principles, independently of any properties of any particular material. The idea of temperature here was in rigid logical consistency with the 'caloric' theory of heat, and it carried out completely the analogy between power derived from the same quantity of heat falling from a higher to a lower level, and resembling a fall of water in producing its effects. For equal quantities of 'caloric,' as of 'water,' temperature fall was regarded as similar to fall in space, and so an accurate idea of the nature of temperature difference is attained.

This definition, however, gave a scale greatly differing from that of mercurial, air, and other thermometers, the degrees defined by it corresponding to larger and larger intervals on the air thermometer as temperature increases. Professor Tait pointed out also that on such a scale the temperature of a body totally deprived of heat is negative-infinite.

All these difficulties do not detract from the fundamental importance of the idea here enunciated for the first time: the idea of an absolute thermometric scale theoretically applicable to all bodies—solid, liquid, and gaseous. On the 'caloric' or 'material' theory of heat, motive power is obtained during the letting down or fall from a higher to a lower level of a given quantity of heat. The quantity of heat does not alter in the process; it is only its relative level which alters. There is no reason, therefore, for mentally limiting the amount of mechanical energy obtainable from any given quantity of caloric, just as there is no reason for limiting the amount of mechanical energy to be mentally derived from a given weight. Any desired quantity of energy may be derived from a weight of, say, one pound, if it only be allowed to fall far enough, assuming gravity to be constant through the range.

The investigation of the work to be derived from a given quantity of heat at a given temperature is thus a matter of experiment, which can be settled by measurement of the properties of a few bodies.

Reasoning, it is conceived, in this way, Thomson follows up his absolute thermometric scale work with an investigation entitled 'Carnot's Theory of the Motive Power of Heat,' described in a paper read in 1849 before the Royal Society of Edinburgh, in which he calculates from Regnault's experiments on steam the power developed by a Carnot reversible engine when using one centigrade heat unit; that is, the heat necessary to heat one pound of water through 1° C. for temperatures from 1° to 231° C., the temperature falling in the engine in each case to 0° C.

In this paper he asks himself two questions: (1) What is the precise nature of the thermal agency by means of which mechanical effect is to be produced without effects of any other kind? and (2) How may the amount of the thermal agency necessary for performing a given quantity of work be estimated?

Using Regnault's values for the properties of steam, he calculates the lines of compression and expansion without heat loss, the lines of compression and expansion with heat flow at the lowest temperature, and heat addition at the highest temperature, and thus arrives at the work area per heat unit let down. He tabulates these results, and shows that what he calls Carnot's function diminishes as temperature rises, using the ordinary centigrade scale. On the caloric theory the methods are rigidly logical and correct, but some inaccuracy is introduced by the necessity of that theory for the discharge of the same amount of heat at the third operation as is taken in on the first. The paper is of great interest, however, because it shows clearly how fully the distinguished author realises the necessity for re-examining the standard ideas of the nature of heat. Two paragraphs make this very clear:—

'7. Since the time when Carnot thus expressed himself the necessity of a most careful examination of the entire experimental basis of the theory of heat has become more and more urgent. Especially all those assumptions depending on the idea that heat is a substance, invariable in quantity, not convertible into any other element, and incapable of being generated by any physical agency; in fact, the acknowledged principles of latent heat would require to be tested by a most searching investigation before they ought to be admitted, as they usually have been, by almost everyone who has been engaged on the subject, whether in combining the results of experimental research or in general theoretical investigations.

'8. The extremely important discoveries recently made by Mr. Joule, of Manchester, that heat is evolved in every part of a closed electric conductor moving in the neighbourhood of a magnet, and that heat is generated by the friction of fluids in motion, seem to overturn the opinion commonly held that heat cannot be generated, but only produced from a source where it has previously existed either in a sensible or in a latent condition. In the present state of science, however, no operation is known by which heat can be absorbed into a body without either elevating its temperature or becoming latent, and producing some alteration in its physical condition; and the fundamental axiom adopted by Carnot may be considered as still the most probable basis for an investigation of the motive power of heat, although this, and with it every other branch of the theory of heat, may ultimately require to be reconstructed upon another foundation when our experimental data are more complete. On this understanding, and to avoid a repetition of doubts, I shall refer to Carnot's fundamental principle, in all that follows, as if its truth were thoroughly established.'

In these two paragraphs Thomson sums up the whole situation in 1849, and promises further investigation and further attempts to deduce the nature of the connection between heat and work.

Assume, then, the truth of the caloric theory of heat, as Thomson does in the 1849 paper: We have a complete theory of the heat engine, based on the Carnot cycle, accounting for efficiencies which vary with temperature differences but requiring no definite mechanical equivalent of heat; nay, antagonistic to the existence of such an equivalent. The caloric theory, as has been pointed out, is quite consistent with the theoretical possibility of obtaining an indefinitely great amount of mechanical energy from any given quantity of heat, provided the *letting down* or fall of level be indefinitely great.

At the time we are discussing—1850—the bare conception of the idea of an absolute zero of temperature is one which is startling in its boldness; and it must have been difficult indeed then to imagine any definite line of proof which could be followed to establish the real existence of such a physical limit. We are so familiar with the existence of very high temperatures, vastly transcending the temperatures in which we personally exist, that we can hardly conceive a temperature limit on the ascending side; that is, we can hardly think of any given high temperature which could not under quite conceivable circumstances be exceeded. We know, for example, that any metal—say platinum—may be melted if its temperature be sufficiently increased; that a further sufficient increase will convert the liquid metal to the gaseous state, and that the gaseous metal may be heated indefinitely while in that state. We know the behaviour and properties of many substances at high temperatures, and are aware of the strong tendency of all chemical compounds, when highly heated, to split up into the elementary bodies composing them. All this we appreciate, but we find it difficult to see how a point of temperature could be reached when it could be said: This is a physical limiting point on the ascending scale; we may heat a substance up to this temperature, but it is impossible to conceive of any higher temperature. It is necessary here to distinguish between a conceivable limit to an ascending temperature and a practical limit under existing conditions. We may thus place limits, say, to the temperature of coal-gas and air explosions, or the temperatures possible from the electric arc; the limit with coal gas and air depending on one set of conditions, and the electric arc upon another set, such as the vapourising point of carbon, and so on. In the same way, at the middle of last century it would have been considered quite reasonable to suppose that human existence was carried on at an intermediate plane of temperature, and that temperatures might exist as low, relatively to our mean temperature, as our known furnace and combustion temperatures are high. At this time, no doubt, such an idea was quite a reasonable one.

No such limit could be proved, even by the aid of the Carnot cycle, reasoning on the material theory of heat. If we assume that heat is material, and that in some way temperature fall doing work resembles, as Carnot supposed, the fall of water doing work in passing from a higher to a lower level, then no absolute zero is possible, because the same quantity of heat is supposed to exist at the low as at the high temperature. On this theory nothing in the idea of temperature suggests a possible physical limit. On the material theory, the notion of temperature is one to which it is exceedingly difficult to attach a precise meaning.

Thomson's promises of further investigation were fulfilled in 1850, in which year he definitely accepted the dynamical theory of heat and finally abandoned the material. His conclusions are given in a memoir of the first importance which was read before the Royal Society of Edinburgh in 1851. It was entitled 'On the Dynamical Theory of Heat.' Before dealing with it, however, it is desirable to consider the work of Joule and others on another side of thermodynamics.

Long before 1850 the equivalence of mechanical work and heat quantity had been accepted by many scientific men, and Rumford had, indeed, made measurements of a rough kind. It remained, however, for Joule experimentally to determine the mechanical equivalent in the most accurate manner and place what is now known as the first law of thermodynamics upon the sure basis of absolute experimental determination. His first paper was read before the Cork Meeting of the British Association in 1843, and at the Oxford Meeting in 1847 he read another—'On the Mechanical Equivalent of Heat'—describing the results of experiments with paddles rotating in liquids driven by falling weights. By these years of work he had absolutely demonstrated the equivalence of heat quantity and mechanical work, so that no loophole of escape seemed possible; it appeared as if the material theory was rendered intellectually impossible to the trained intellect. This was not the fact, however, as is evident from both Joule's and Thomson's accounts of that British Association Meeting.

Joule's earlier paper had been coolly received. Indeed, it is evident that the idea of a mechanical equivalent of heat was still distasteful to the physicists of the day, and its discussion was looked upon with dislike. Joule, at the 1847 Meeting, addressed a small audience, and the account of his experiments was received without enthusiasm. This adverse atmosphere, so discouraging to the investigator, was quickly removed, however, when a young man rose to make his remarks, and, by his enthusiastic comment and clear reasoning, at once succeeded in attracting the interest of those present. This young man was William Thomson, Professor of Natural Philosophy in the University of Glasgow. Speaking of this, his first meeting with Joule, at Manchester forty-six years later, Lord Kelvin said: 'I can never forget the British Association at Oxford in the year 1847, when in one of the Sections I heard a paper read by a very unassuming young man, who betrayed no consciousness in his manner that he had a great idea to unfold. I was tremendously struck with the paper. I had first thought it could not be true because it was different from Carnot's theory, and immediately after the reading of the paper I had a few words of conversation with the author, James Joule, which was the beginning of our forty years' acquaintance and friendship. . . . I gained ideas which had never entered my mind before, and I thought I, too, suggested something worthy of Joule's consideration when I told him of Carnot's theory.' This meeting was indeed fateful for the future of the science of thermodynamics, as it resulted in co-operation between two men of giant intellect, who between them performed most of the experimental work which was necessary to make thermodynamics an exact science. Their work alone sufficed to place the first and second laws of thermodynamics on the firm footing of accurate experiment and logical deduction.

Although Thomson was much struck by Joule's experiments, he did not accept the dynamical theory of heat at once. As he stated himself: 'I had first thought that it could not be true because it was different from Carnot's theory.'

Joule's discoveries at this date may be thus expressed:—

Heat and mechanical energy are mutually convertible, and heat requires for its production, and produces by its disappearance, mechanical energy in the proportion of 1,390 foot-pounds for each centigrade heat unit, a heat unit being the amount of heat necessary to heat one pound of water through 1° C.

Knowing, as Thomson did, that mechanical energy could be produced by the agency of heat, but that its amount varied with the temperature and temperature fall, Joule's discoveries seemed antagonistic to Carnot's demonstration; and, convinced as he was that Carnot's law was true, he naturally felt at first that there must be some other way of looking at Joule's results than that adopted by Joule himself.

Joule naturally believed in his own manner of looking at his results, and he apparently agreed with Thomson as to the antagonism between what may be here called the Carnot and Joule laws.

The material theory of heat might have been true; in which case there was no more need for any direct quantitative connection between heat quantity and mechanical energy than between the mass of a body and its mechanical energy. Any unit of mass may acquire any conceivable amount of mechanical energy if its velocity be great enough, and so any unit of heat on the caloric theory may produce any conceivable amount of mechanical energy if the temperature fall be great enough. Joule considered the Carnot law to be so inconsistent with his law that in one of his papers he proposes its abandonment as inconsistent with discovered facts. At this point the two ideas seem to be in opposition. The germ of reconciliation, however, is found in observations by Thomson in both the 1848 and 1849 papers. In paragraph 8, quoted here from the latter paper, it is stated:—

'In the present state of science, however, no operation is known by which heat can be absorbed into a body without either elevating its temperature or becoming latent and producing some alteration in its physical condition.'

This is equivalent to saying that no case has been observed where heat disappears doing mechanical work. In a note occurring in the same paper he alludes to the fact that engineers always assume that the amount of heat found in the condenser of the steam engine was the same as that taken into the engine by the steam, in the following terms:—

'So generally is Carnot's principle tacitly admitted as an axiom that its application in this case has never, so far as I am aware, been questioned by practical engineers.'

This was quite accurate. Hirn's demonstrations that heat disappears in a steam engine when work is done was not made until 1857, eight years later.

In the 1848 paper he states:—

'The experiments of Mr. Joule of Manchester seem to indicate an actual conversion of mechanical effect into caloric. No experiment, however, is adduced in which the converse operation is exhibited; but it must be confessed that as yet much is involved in mystery with reference to these fundamental questions of natural philosophy.'

Here we find Thomson's mind engaged—in 1848 and 1849—with the very matter requiring proof. Joule had proved the generation of heat by means of mechanical work; Thomson required the proof of the converse case—the disappearance of heat when mechanical work was done by the working fluid.

This proof was forthcoming in the results of experiments on the compression and expansion of air. Accordingly, we find the Carnot and Joule principles reconciled in Thomson's paper of 1851, and the important deduction made of an absolute zero of temperature at $-273°$ on the Centigrade scale. The introduction of the idea of the mechanical equivalent of heat leads at once to an absolute zero of temperature, and allows of the determination of this physical lower limit by the use of the Carnot cycle for investigating the efficiency of a perfect engine using any working fluid. Air was the working fluid actually investigated, and the determination of its properties at ordinary temperatures was a vitally important result of the co-operation of Thomson and Joule. Their experiments lasted for many years, and their rigorous investigation disclosed the fact that internal work was done in expanding a gas; in fact, that in a gas expanding isothermally doing work, part of the heat only disappeared in external work and part was absorbed in separating the molecules.

The Joule and Carnot laws are now known as the first and second laws of thermodynamics.

The second law, in modern form, may be thus stated:—

Although heat and work are mutually convertible and in definite and invariable proportions, yet no conceivable heat engine is able to convert all the heat given to it into work. Apart altogether from practical limitations, a certain portion of the heat must be passed from the hot body to the cold body in order that the remainder may assume the form of mechanical energy.

The proportion of the total heat convertible into mechanical energy depends on the absolute temperatures of the hot and cold bodies; it is unity *minus* the lower absolute temperature upon the upper absolute temperature.

It appears that during Thomson's struggle to reconcile the two apparently opposing laws, Clausius, who had seen the same difficulty, arrived independently at its solution and published a paper, 'On the Motive Power of Heat and the Laws of Heat which may be deduced therefrom,' at the Berlin Academy in February 1850. In this paper, Clausius discusses Thomson's difficulties, and also arrives at the conclusion that the Carnot cycle may be reconciled to Joule's law by the omission of the supposition that during the third process the same amount of heat is discharged from the cool body as was taken in from the hot one. He states:—

'On a nearer view of the case we find that the new theories were opposed not to the real fundamental principle of Carnot, but to the addition that no heat is lost. For it is quite possible that in the production of work both may take place at the same time: a certain portion of heat may be consumed and a further portion transmitted from a warm body to a cold one; and both portions may stand in a certain definite relation to the quantity of work produced. This will be made plainer as we proceed; and it will be moreover shown that the inference to be drawn from both assumptions may not only exist together, but that they may mutually support each other.'

In his 1851 paper, Thomson gives Clausius full credit for solving the difficulty between the Carnot and the Joule principles. Thomson gives Clausius the full credit for priority, but states that he was working on the same problem and had arrived at the same solution in the year 1850, before he had seen Clausius' work. Clausius, however, assumed the theory of a permanent gas, which required the absence of internal work, but Thomson was not prepared to assume this without experiment. This determination rigidly to prove every necessary assumption, and his clear conception of the points necessary for proof, led to the extensive series of researches undertaken by Thomson and Joule with the object of determining how much gas thermometers differ from an absolute scale as determined by the combination of the Joule and Carnot laws.

Rankine, as early as 1849, arrived at the general equation of thermodynamics which expresses the relation between heat and mechanical energy, and indicated the result of his investigations to the Royal Society of Edinburgh in February 1850. Rankine thus arrived independently at the same result as Clausius about the same time. Both Rankine and Clausius, however, adopted certain theories as to the molecular structures and motions of gases, and their demonstrations to some extent depended upon their theories. To Thomson and Joule we are deeply indebted for the rigid proof of the two laws and for the rigid deduction of the modern scale of temperature and the determination of absolute zero in its modern form. Thomson now thus defines temperature:—

'The temperatures of two bodies are proportional to the quantities of heat respectively taken in and given out in localities at one temperature and at the other respectively, by a material system subjected to a complete cycle of perfectly reversible thermodynamic operations, and not allowed to part with or take in heat at any other temperature; or, the absolute values of two temperatures are to one another in the proportion of the heat taken in to the heat rejected in a perfect thermodynamic engine, working with a source and refrigerator at the higher and lower of the temperatures respectively.'

This definition leads to an absolute scale of temperature which is independent of the substance operated on, and Joule and Thomson's experiments have shown that this scale differs but slightly from that of the ordinary air thermometer. Joule had suggested to Thomson, in a letter to him in 1848, that the probable value of Carnot's function is the reciprocal of the absolute temperature as measured on a perfect gas thermometer.

Thus Clausius appears to have anticipated Thomson, not in the suggestion of an absolute scale of temperature, but in the idea of an absolute zero founded upon the combination of Carnot's law and Joule's law. Thomson, in his papers, very modestly attributes the second law—the law of the transformation of heat—to Carnot and Clausius; but in this he undervalued his work, because Clausius appears to have assumed what Thomson and Joule proved; that is, the coincidence of the absolute scale with the air thermometer scale.

It will thus be seen that the position usually assumed by the engineer at 1850, of the equality between heat given to the engine and heat given to the condenser, was fundamentally untrue. Without this deduction, however, no determination of values of the Carnot function could have led to the determination of an absolute zero. According to the material theory, as seen in the light of Carnot's cycle, a heat unit could give an indefinitely increased amount of work with lowering of the temperature. Nothing in the theory sets a limit to this increase, and, accordingly, there is nothing to suggest an absolute zero. Immediately, however, we accept the dynamical theory of heat we find that a pound of water requires the exertion of 1,390 foot-pounds of work to heat it through 1° C. We also know from the Carnot cycle that under ordinary conditions of human existence only a portion of this work can be returned; but as no conditions could conceivably exist in which a greater amount of work could be obtained from a pound of water than the 1,390 foot-pounds put into it to heat it through 1° C., it follows that, inasmuch as the Carnot function increases with diminishing temperature, the limit of temperature is reached when, according to the Carnot cycle, the whole of that work, put into the pound of water, can be got out again as work. This limit is the absolute zero of temperature. No lower temperature is conceivable without introducing the idea of the creation of energy. So far as human beings are concerned, this idea is as inconceivable as the idea of the creation of matter. The determination of this limit with the close accuracy necessary for a well-founded constant is to be entirely attributed to Thomson and Joule. In his 1851 paper Thomson thus succeeds in answering the questions which he put to himself in his 1849 paper, and he supplies a quantitative method of connecting the amount of the thermal agency necessary with the amount of work which can be performed under varying conditions.

Engineers dealing with motive power are thus deeply in debt to Thomson and Joule for the secure position occupied by them to-day.

The brilliant work of Meyer, published so early as 1842, is held by some to have anticipated to a large extent both the work of Thomson and of Joule. Undoubtedly Meyer formulated true ideas and carried his generalisations through a wide range. Helmholtz also very early arrived at similar conclusions to those of Joule and Thomson; but it has been thought better to discuss the work of Thomson and Joule separately, in order to illustrate the transition period through which many distinguished minds were passing about the time. Undoubtedly great credit is due to Meyer, Helmholtz, Clausius, and Hirn, and Thomson himself recognised this in the most generous way.

The ideas of Thomson and Joule now form so much of the basis of all reasoning upon motive-power engines that there is some little danger to the present generation of forgetting what they owe to these two great men. To appreciate the step made by them it is necessary to consider the position of motive power produced by heat at about the middle of the last century. At that time many attempts had been made to displace the steam engine as a heat engine by air engines in various forms—both engines heated externally and those heated internally, now known as internal-combustion engines. Papers read at the Institution of Civil Engineers in 1845 and 1853, and the discussion of those papers by eminent men of the day, supply an accurate measure of the knowledge possessed by the engineer of the principles of action of his heat engines. Many distinguished names occur in these papers and discussions, including James Stirling, Robert Stephenson, Sir George Cayley, Charles Manby, James Leslie, C. W. Siemens, Hawksley, Pole, W. G. Armstrong (afterwards Lord Armstrong), Edward Woods, E. A. Cowper, D. K. Clark, Benjamin Cheverton, Goldsworthy Gurney, George P. Bidder, Professor Faraday, Isambard K. Brunel, Captain Fitzroy, and F. Braithwaite. At the date of the later of these discussions Brunel had already designed the 'Great Eastern,' in 1852, with its engines of 11,000 h.p. Armstrong was a Fellow of the Royal Society, and had started the Elswick Works and invented the Armstrong gun. Robert Stephenson was at the height of his fame. He was then a Member of Parliament, President of the Institution of Civil Engineers, and a Fellow of the Royal Society. Siemens was a young man, but was busy on the regenerative furnace; had considered regeneration as applied to steam engines, although his work on the air engine was still to come. All were distinguished men in their day, and their opinions may be taken as representing the very best scientific knowledge of the leading engineers of the day. The first of the papers to which I refer is called 'Description of Stirling's Improved Air Engine,' by James Stirling, M.Inst.C.E. It was read on June 10, 1845, with Sir John Rennie, the President of the Institution, in the chair. The engine described was the later form of the well-known Stirling air engine, invented by the Rev. Dr. Stirling, a Scottish clergyman, in the year 1815. The development considered was the invention of the reader of the paper, a brother of Dr. Stirling. The main improvement consisted in the use of air at a greater density than the atmosphere, and the engine at that date had so far succeeded that two had been used at the Dundee Foundry Company's works—one giving about 21 h.p. and the other about 45 h.p. Practically, therefore, some success had been attained. Mr. Stirling claimed that the 21-horse engine consumed 50 lb. of coal per hour, which is about $2\frac{1}{2}$ lb. per horse-power per hour. This was an extraordinarily good result for the time. At present, however, we are not interested in the practical result, but only in the opinions of the engineers of the day as to the fundamental principles of heat engines.

It is clear from the paper that the theory of the regenerator was entirely misunderstood. It was imagined that with a perfect regenerator no heat would be required to perform work. This is evident from Mr. Stirling's answer to Sir George Cayley. Sir George Cayley described his engine, which was of the internal-combustion type, acting with solid fuel under constant pressure, and showed that, owing to dust and heat in the cylinder and valves, his experiments proved abortive. He stated, however, that his engine had consumed $6\frac{1}{4}$ lb. of coke—equal to 9 lb. of coal—per horse-power. To this Mr. Stirling answered: 'It must be remarked that Sir George Cayley, in following an entirely different object, had overlooked the great leading principle of repeatedly using the same heat,' and 'he was of opinion that, except on that principle, the air could not be economically used as a moving power.' Another speaker, Mr. Cottam, said: 'It was evident that, if it was practicable to arrive at the theoretical condition of the absorption of all the caloric by the thin laminæ during the upward passage of the air and the giving it out again during the downward passage, there would not be any loss of heat.' Mr. Robert Stephenson did not appear to understand Stirling's air engine at all, because he made the following remarks: 'He understood the process to consist of heating the air in a vessel, whence it ascended to the cylinder between numerous thin laminæ, by which the caloric was absorbed, to be again given out to the descending air. Now it appeared to him that, though the ascending process was natural and easy, the reverse action would require a certain expenditure of power, in the depression of the plunger.' This remark clearly showed that Stephenson, notwithstanding his eminence as an engineer, at that date had not appreciated the essential conditions of the hot-air engine.

In the year 1853 the subject of the air engine again came up before the Institution of Civil Engineers, interest being excited evidently by the building of the large engines of the hot-air ship 'Ericsson' in America, the engines having air cylinders of no less than 14 feet diameter. Four papers were read in this year: 'On the Use of Heated Air as a Motive Power,' by Benjamin Cheverton; 'On the Caloric Engine,' by Charles Manby; 'On the Principle of the Caloric Air Heated Engine,' by James Leslie, M.Inst.C.E.; and 'On the Conversion of Heat into Mechanical Effect,' by Charles William Siemens, A.M.I.C.E.

Cheverton evidently considers, from his paper referring to Stirling and Ericsson, that 'Both parties also rest the efficiency of their engines on the repeated use of caloric. They contend that in recovering from the ejected hot air the caloric which gave it superior tension, and employing it in heating the injected air, "it is made to operate over and over again." Mr. Ericsson aspires to embody a new principle in motive mechanics—no less, to use his own words, than "that the production of mechanical force by heat is unaccompanied by the loss of heat," except such as arises from radiation, or other practically unavoidable waste.' Cheverton rejects this idea, but, strangely enough, does not appear aware of the work either of Carnot or of Joule. He comes to the conclusion, however, that 'caloric, doubtless, is in all its aspects a manifestation of force, and unquestionably, as a mechanical agent, of a dynamic force, and therefore is directly amenable to the third law of motion.' He appears to think that heat is accompanied with molecular activity, but is puzzled by what he accepts to be a fact, that in the steam engine the whole of the heat of the steam as it comes from the boiler is found in the condenser. With regard to the steam, he says: 'Undoubtedly, in respect to the materiality of caloric, if it be material, it is transferred intact to the condenser, yet in its passage it may have parted with force, which it cannot communicate again.' He comes to the conclusion that the change may take place not in the quantity, but in the intensity of heat. Here he resembles Carnot; but it appears to him impossible to arrive at any useful theory of the heat engine, because he states: '. . . for every investigation leads to the conclusion that the effect of caloric is independent at least of the chemical, if not also of the physical, constitution of bodies. But economy of fuel is a different question from the economy of caloric; it is altogether a practical matter, and can only be determined by experiment; for this, and, indeed, most other points of practice, are too intractable to come within the grasp of the most powerful calculus.' In the discussion a communication was read from Sir George Cayley, in the course of which he states, with regard to the regenerator: 'There can exist no doubt of the effective re-application of heat to an almost unlimited extent by this beautiful invention, due originally to Mr. Stirling, and now carried out to a greater extent by Captain Ericsson.' Sir George Cayley discussed the difficulties of Ericsson's engine, but he accepts the principle that heat may give work and yet be used over and over again practically undiminished. Armstrong did not express himself upon the theory at all, but he was doubtful as to the advantage of the air engine compared with the steam engine, although he believed that it was practicable to recover and use over again a large proportion of the heat applied, and he thought the balance of economy, so far as heat was concerned, would be found in favour of air. Siemens agreed to some extent in the advantages of a regenerator, but he showed clearly that expansion doing work was accompanied by a diminution of temperature, and stated that this heat had to be replaced by the fire. Bidder was of opinion 'that no theoretical advantage was obtained in using heated air instead of vaporised water as a motive power, and it was incapable of being applied practically with as much convenience.' It is most interesting to note that Dr. Faraday joined in this discussion. He said very little, and I will give his remarks complete. Dr. Faraday said: 'Twenty years ago he had directed his attention to this question, and from theoretical views he had been induced to hope for the successful employment of heated air as a motive power; but even then he saw enough to discourage his sanguine expectation, and he had, with some diffidence, ventured to express his conviction of the almost unconquerable practical difficulties surrounding the case, and of the fallacy of the presumed advantages of the regenerator. He still retained his doubts as to the success of the innovation, and feared the eventual results, even of Captain Ericsson's spirited and ingenious efforts.' Brunel considered the use of the regenerator to be an entire fallacy, and did not believe that the power derived from the expansion of air by heat could be used effectively, and then be recovered and used again. Mr. Hawksley considered that the machine involved a mechanical fallacy and that the regenerator produced no mechanical effect whatever. Mr. Rendel was the President at the meeting which dealt with Mr. Cheverton's paper, and, in view of the great differences of opinion on the subject, he stated that 'he would not have the meeting arrive at a hasty or erroneous conclusion on the question of this engine, and he therefore suggested that Mr. Siemens should draw up a paper on the subject, and that the members should collect, for a future meeting, all the information within their reach, in order to the calm and deliberate discussion of the question.' This resulted in the further meeting of May 17, 1853, when papers were read by Manby, Leslie, and Siemens. The paper by Manby consists of the summary of a discussion by M. Galy-Cazalet, which took place in Paris in 1852. M. Galy-Cazalet comes to the conclusion that the regenerator involves a fallacy, and he concludes: 'There appears to be at present so much doubt of the utility of the regenerator that it would be wise to abandon its use for a time, and by trials with a more simple form of caloric engine establish the fact either of the superiority or of the inferiority of heated air in comparison with steam as a motive power.' Mr. Leslie, on the contrary, in his paper upholds vigorously the accuracy of the principle of the regenerator or economiser. He comes to the conclusion that it is based on true principles and is attended in practice with real economy of heat, and consequently of fuel. In this conclusion he is doubtless correct; the regenerator is useful and does economise heat. But Leslie goes much further than this; he appears to support Stirling in the fallacy that the regenerator may be made indefinitely useful. Stirling states:—

'And thus it appears that by applying air successively to a series of bodies regularly increasing in temperature, and moving it alternately from one end of the series to the other, it may be heated and cooled ten times, with an expenditure of caloric which would barely have heated it once, if if had been applied at once, to the hottest body (*i.e.*, beyond the series). It is evident also that if the series had been composed of twenty points, or bodies, having a difference of temperature of five degrees, the air might be heated and cooled twenty times at no greater expense of caloric. Nay it is evident that by multiplying the members of the series indefinitely air could be heated and expanded and made to do work at no appreciable expense. But let no mathematician be alarmed with the idea of a perpetual motion, or the creation of power. There are many enemies to contend with in the air engine besides friction, which alone prevents perpetuity in some mechanical motions. We have no means, without consuming a part of our power, of applying the air so closely to the apparatus as to make it absolutely assume the temperature of the bodies to which it is applied. There is, therefore, a loss in the very act of heating and cooling.'

Leslie comes to the conclusion that Stirling is right, but that an air engine without a regenerator would be a much less effective and economical application of heat than the steam engine. Leslie gives some interesting particulars of the later air engines of James Stirling. He states that an engine of 45 h.p. was started in March 1843 at the Dundee Foundry; that in December 1845—two years and nine months after starting—one air-vessel gave way, and in May 1846 another failed, and in January 1847 a third failed. This information was supplied to him by Mr. David Mudie, one of the lessees of the foundry.

We now come to Siemens' paper 'On the Conversion of Heat into Mechanical Effect,' and for the first time we find the engineer guided by an intelligible principle. Siemens discussed the material theory of heat, and accepted unreservedly the dynamical theory, for which he gives a large measure of credit to Joule. This is the first of the Institution papers in which I find the name of Joule. Siemens mentions Carnot, Clapeyron, Holtzman of Mannheim, Joule, Helmholtz, Meyer, Rankine, and Professor Thomson. Curiously enough, although Siemens mentions Carnot and the other philosophers who dealt with the Carnot principle, including

Thomson, he does not appear at this date—May 17, 1853—to have realised himself the effect of the law of Carnot upon the theory of the heat engine. He clearly appreciated the first law, and gives the mechanical equivalent of heat as determined by Joule at 770 foot-pounds, and by Thomson's formula as 772 foot-pounds, but in his discussion of the principles of the heat engine he is of opinion that a perfect engine is ideally possible giving 770 foot-pounds for each Fahrenheit heat-unit employed. This is clear from a table found on page 33 of the paper, which I reproduce:—

Siemens' Table of 1853.

Description of Engine	Theoretical Performance in foot-pounds	Actual Performance in foot-pounds	Actual Performance in pounds of Coal per H.P. per Hour
A Boulton and Watt condensing engine, low pressure	51·8	29	8·00
The best Cornish engine .	158·8	82	2·38
Combined steam and expansive ether engine .	150·0	75	3·09
The expansive air engine .	91·0	35	6·63
Stirling's engine . . .	130·0	65	3·57
Ericsson's engine . .	196·0	65	3·57
A Perfect engine . .	770·0	385	0·60

He apprehends the mechanical equivalent of heat, but he still appears under the impression that if heat be added to a certain upper temperature and expansion take place until the original temperature is reached, then he has a perfect engine indicating the full result of Joule's mechanical equivalent. He sees, however, that the old theory of the regenerator is quite wrong. He states:—

'The cause of the failure of Mr. Stirling's engine in practice may apparently be traced chiefly to insufficiency of heating surface, occasioned apparently from misapprehension of the principle involved, it having been thought that the same heat would serve over and over again to produce power, and that the necessary expenditure of heat consisted only in the mechanical loss by imperfect action of the respirative plates, which were approached to each other to the utmost limits, consistent with an unobstructed passage of the air. By the aid of the dynamical theory of heat it has been shown that there is another and far more important expenditure of heat, which should have been provided for.'

Siemens, in the discussion, rightly upheld the regenerator as useful, and saw that there were limitations to its use. Mr. Hawksley contended that the regenerator was useless. Mr. Pole considered that the regenerator was useful, but he did not definitely adopt the mechanical theory of heat. He stated:—

'It must be allowed that the general action of caloric in producing power was still involved in much obscurity. The heat was often considered in reference to its quantity only, but it was certain also that its intensity performed a very important part; and it had even been surmised that power might be obtained by the reduction of intensity alone, without any change of quantity.'

Armstrong concurred with Siemens and Pole. He believed in the utility of the regenerator, limited as described by both. Mr. Edward Woods certainly understood Siemens to have given 772 foot-pounds as the efficiency of an ideal heat engine, because he stated that this showed there was still great room for improvement in engines. Mr. E. A. Cowper had clear ideas; he said:—

'Steam, or gases, in expanding, and so giving out power, lost heat. Part o the sensible heat became latent in the production of power, and this heat could only be recovered by expending the power already produced in again condensing the steam back to its original bulk, when the latent heat again became sensible.'

This discussion, then, puts us in the position of engineers at the date of the last meeting referred to—May 17, 1853. Of all the distinguished engineers who spoke, Siemens alone had thoroughly apprehended the value of Joule's results and understood the full bearing of the mechanical equivalent of heat. He had not, however, understood Carnot's reasoning on the Carnot cycle, or Thomson's deductions from Carnot. He was under the impression that heat added in any way to a working fluid, raising the temperature, could be entirely converted into work by a sufficient expansion. He had not appreciated that, even if expansion be carried far enough to reduce the temperature to the original temperature before heat addition, yet complete conversion of the entire mechanical equivalent was impossible. When so able a man as Siemens had at this stage only reached partial enlightenment, it was evident that much hard work and clear thinking required to be done before a well-founded theory of heat motive-power could be obtained. The data for such a theory was accumulating; and one of the most interesting circumstances connected with these Institution of Civil Engineers papers was a communication from M. Regnault to Colonel Sabine, Treasurer of the Royal Society, dated April 1853, which was read at the meeting, in which Regnault stated that

'He was about to publish immediately a series of elaborate experimental researches on various subjects connected with the effects of heat on elastic fluids, the results of which would solve many questions long in dispute, and by means of which engineers might accurately calculate the effect of a given amount of fuel, in whatever way it was applied. M. Regnault communicated in anticipation that he had arrived at the number 0·237 for the specific heat of air at constant pressure, and at 0·475 for that of steam under atmospheric elasticity, the specific heat of water being taken in each case as unity.'

True to his word, Regnault produced his admirable investigations, and succeeded in solving many problems; but he did not settle the questions to the extent he had hoped. Even at the present time doubt arises as to the very values he gave for the specific heat of air and steam. The problem proved much more difficult than he had anticipated, and for modern engine purposes it cannot be considered as wholly solved now—fifty-five years later.

This description of the position of the hot-air engine, as shown by the opinions of eminent engineers, is most useful as proving how much practical men were in need of the work of Thomson and Joule. It is not surprising that, of all the engineers present, Siemens appeared to be alone in thoroughly grasping the new ideas. Thomson's own conversion from the material theory of heat to the dynamical theory was not complete until 1851, and although he had then succeeded in reconciling the ideas of Joule and Carnot, it is not to be wondered at that engineers two years later had not quite succeeded in grasping the combination of the two laws. This combination, however, supplied engineers with a new and accurate standard of measurement for studying and improving upon their heat engines, and they were by no means slow in grasping the help thus offered them by the abstract scientific man. The broad laws of thermodynamics have placed the theory of the heat engine in a position of certainty, which was much needed. It would be a mistake to assume, however, that even the determination of the mechanical equivalent of heat and the second law of thermodynamics expressed in terms of an absolute thermometric scale had solved all the difficulties of the engineer desiring to determine the efficiency of his heat engines. Thomson

Joule, Rankine, and their great Continental colleagues, it is true, settled once and for all the broad laws of thermodynamics, but the Carnot cycle is a cycle which is, as has been repeatedly shown, an impossible one in practice. Accordingly actual engines have to operate upon imperfect cycles. The theory of these imperfect cycles has been worked out mostly during the last twenty-five years, although Rankine made a beginning in dealing with the theory of the Joule air engine. For the first time he showed the existence of what may be termed a cycle of constant efficiency in the case of the Joule air engine. Assuming constant specific heat for the working fluid, he calculates the efficiency of what we now call a constant-pressure air engine between certain limits of temperature, and he gives the efficiency of the fluid where U = energy exerted and H_1 = heat received, and r = ratio of compression and expansion :—

$$\frac{U}{H_1} = 1 - \frac{1}{r^{0 \cdot 408}};$$

that is, he indicates in this formula that the thermal efficiency is independent of the maximum temperature as long as that maximum temperature exceeds the temperature of adiabatic compression. He makes no statement, however, that this engine is within a certain range independent of the maximum temperature; that is, that increasing maximum temperature does not increase efficiency. Subsequent work has shown that, on a simple assumption, such as constant specific heat, many engine cycles exist of a practicable nature having high theoretical efficiencies where the theoretical efficiency depends on one thing only—the ratio of compression. Some misunderstanding has arisen with regard to these imperfect cycles, and it has even been thought that such imperfect cycles would be contrary to the second law of thermodynamics. Lord Kelvin himself was of this opinion in 1881. I vividly remember a conversation I had with him at the Crown Iron Works, in Glasgow, over the results I had obtained from one of my early gas engines. I had then come to the conclusion that the 'Otto' cycle as ordinarily operated was a cycle of constant efficiency, and I explained this to Lord Kelvin. He had not followed such cycles, and his view then was that no such cycle could exist, because he thought it was contrary to the second law of thermodynamics. Some idea of this kind has been held by many scientific men, and has prevented the minute investigation of imperfect cycles of different kinds, because of the feeling that the whole question of efficiency was entirely settled by the nature of the temperature limits; that is, by the maximum and minimum temperatures at the disposal of the engineer. It is true that these values, as has been shown, must always determine the extreme limit of possible efficiencies between certain temperatures, and in cycles of constant efficiency the particular efficiency of the cycle is always less than the efficiency of a Carnot cycle engine working between the same limits of superior and inferior temperature. The investigation, however, of these imperfect cycles is much more difficult than the broad investigation of the general thermodynamic laws, because it requires accurate knowledge of the properties of the working fluid dealt with under conditions rendering observation extremely difficult. The modern internal-combustion motor is the successor to the air engine so fully discussed by eminent engineers of fifty-five years ago; and the forebodings of even so eminent a man as Faraday as to its ultimate success have proved unfounded. Great difficulties have been encountered and many discrepancies have had to be explained, but a minute study of the nature of the working fluid has rendered it more and more possible to calculate the efficiencies to be expected under practical conditions. At the present time we can deal with almost any cycle or any working fluid with some fair approximation to an accurate result. Much work, however, is required before all problems of the working fluid can be said to be solved with regard to any heat engine. Indeed, it may be said that under modern conditions of the use of steam even the properties of the working fluid—steam—have not yet been satisfactorily determined. The mere question of specific heat, for example, of steam and its variations of temperature and pressure is now under review, and important experiments are in progress in Britain and on the Continent to determine those properties. The properties of the working fluid of the internal-combustion motor are also the subject of earnest study by many Continental and British investigators. Notwithstanding all the perplexities involved in the minute study of the imperfect heat engine cycles, we are in a very different position to-day compared with the engineer of 1853. We know all the broad laws as to the conversion of heat into work or of work into heat; and, numerous as are the problems yet to be solved, we at least profit by the guiding light set out for us by Kelvin, Joule, and Rankine.

The following Paper was then read:—

Recent Advances in Steam Turbines.[1]
By GERALD STONEY, *B.E.*, *M.Inst.C.E.*, *M.I.E.E.*

This paper was a continuation of one read by the author at the York meeting in 1906, and showed the rapid progress that has been made in steam turbines during the past two years. Improvements in electric machinery, both in the form of continuous-current dynamos and also alternators driven by steam turbines, were dealt with, as well as the application of the steam turbine to air compressors and for pumping water, &c. The use of exhaust-steam turbines for utilising the exhaust from reciprocating engines was described, and also of intermittent supplies of exhaust steam, such as from winding-engines, by help of thermal accumulators, along with the further refinement of mixed-pressure turbines, where, when the supply of exhaust-steam fails, a high-pressure portion is brought into action, thus utilising the full boiler-pressure. Improvements in condensers and the various means to obtain the highest vacuum possible were also described.

In marine work the great development of express liners on the Atlantic was dealt with, and also the combination of reciprocating engines and turbines for tramp steamers and vessels of low speed, from which combination greater economy can be obtained than with either steam turbines or reciprocating engines alone.

FRIDAY, SEPTEMBER 4.

Joint Discussion with Sections A and B on Gaseous Explosions.

MONDAY, SEPTEMBER 7.

The following Papers were read:—

1. *The Utilisation of Peat for making Gas or Charcoal with Recovery of By-products.*[2] *By* Captain H. RIALL SANKEY, *R.E.*, *M.Inst.C.E.*

The much-discussed subject of the utilisation of peat has during the last few years been revived owing to developments in gas producers and in gas engines, and at the moment it is of considerable interest in Ireland in connection with the Bill which has been promoted in Parliament to obtain powers to produce gas from peat, to use this gas for making electricity by means of gas engines and dynamos, and to distribute electric power to works which will probably be established in the immediate neighbourhood of the power station and throughout a certain

[1] Published in the *Electrician*, September 11.
[2] Published in *Engineering*, September 11.

prescribed district. It is proposed to put the power station alongside the Grand Canal, not far from Robertstown, about twenty-five miles from Dublin.

Previous attempts to utilise peat for power failed because they were based on drying the peat, so as to contain no more than 25 per cent. of water, and in some cases the expense of 'briquetting' was incurred; the peat was then transported to the place where power was required and burnt in steam boilers fitted with specially designed furnaces. Such peat could not compete with coal; moreover, the valuable by-products were not recovered.

In the proposed scheme the peat will only be partially dried—that is, will still contain 60 per cent. of water; it will be used on the spot to make gas, so as to get the benefit of the great thermal efficiency of gas engines and to save the cost of carriage. The by-products will be recovered, the profit on which will at least cover the cost of getting and drying the peat. It will be possible to supply power to works in the immediate neighbourhood of the power station as cheaply as can be done from water-power. Many of those industries which are dependent upon cheap power will undoubtedly be attracted.

Great progress has been made in Germany in the utilisation of peat. Although no complete electric-power undertaking is at present working on the above lines, all the various links in the chain are separately and successfully in operation; many of these links have been 'Made in Germany,' why should not the complete chain be put together in Ireland?

There are several methods of getting and drying peat. Apparently, the most suitable, when it is desired to obtain peat nearly all the year round, is to dig with a grab, and pass the peat through a Dornberg press. The peat then rapidly dries to 60 per cent., except in very wet weather in the winter, and to tide over this period a reserve of peat must be accumulated.

The producers used for making gas from peat are similar to those used with bituminous coal, but they are larger in dimensions for the same power. The gas issuing from the producers passes through the recovery plant, thence to the gas engines. The gas in passing through the recovery plant is cleaned in a very perfect manner, and therefore troubles due to tar and dust are entirely obviated.

Sulphate of ammonia is the principal by-product. The amount obtained depends on the percentage of nitrogen in the peat. The proposed power station at Robertstown will be capable of making 3,000 tons of sulphate per annum.

The other important by-products are acetate of lime, methyl alcohol, and tar containing paraffin wax and oils. An excellent waggon grease can be made from the tar, the output of which at Robertstown ought to be about 2,000 barrels per annum. The monetary value of these by-products will be about equal to that of the sulphate of ammonia.

An excellent charcoal can be made from peat, instead of gas, together with the by-products enumerated above, and the process has been in operation near Oldenberg for over ten years. The most up-to-date factory, however, is at Beuerberg, near Munich, and it has been at work for three years. The charcoal obtained from peat is of excellent quality, and can be used to advantage to replace wood charcoal. It is used in large quantities in Germany in connection with the manufacture of steel.

2. *Producer Gas.*[1] *By* J. Emerson Dowson, *M.Inst.C.E.*

The author's first paper on this subject was read at the York Meeting in 1881, and after twenty-seven years he reviewed briefly the progress since made. In large furnace-work he traced the developments and improvements in the system introduced by the brothers Siemens. Its success has been great, and has been due chiefly to heating the air for combustion by the waste products. Dr. Mond's recovery of ammonium sulphate, which reduces the cost of fuel, is also mentioned. For smaller heating work, where jets of gas are required, it is essential that the

[1] Published in *Engineering*, September 11.

gas should be clean, of good quality, and of uniform pressure. This is especially necessary where the gas must be burnt with air at pressure, as for blow-pipes, &c. Producer gas is now used for the following as well as many other purposes: Cooking and baking in hospitals and asylums, japanning and enamelling, type-founding, varnish making, melting in crucibles, cutting and finishing glass, heating tailors' irons in clothing factories, and laundry irons, calenders, &c., gassing silk and cotton yarns, singeing textile fabrics, soldering biscuit and condensed-milk tins, &c., annealing, hardening and tempering, boiling sugar, roasting coffee, cocoa, and other food-products in factories. Notwithstanding this the author considers that, in proportion to the immense amount of heating required in the various industries throughout the Kingdom, more progress would have been made if manufacturers and others knew more about the subject technically. Often they do not seem to understand the treatment of gas, or what can be done with it. Undoubtedly the greatest development in the use of producer gas has been with gas engines. A gas engine was worked for the first time with producer gas in 1879, in a plant devised by the author. The calorific power of producer gas is the same now as then, but less gas is now consumed per h.p., owing to improvements made in the engines. The meaning of *pressure* and *suction* gas was described. In 1862 Dr. Jacques Arbos of Barcelona patented a gas producer worked by the suction of an engine, but the first to deal with this in a practical way was M. Léon Bénier of Paris (1891). Various modifications and improvements have since been made, and the suction plant is extensively used. The chemical reactions on which pressure and suction gases depend are identical, but the calorific power of pressure gas made with a jet of superheated steam is usually considerably higher than that of suction gas. For heating purposes in small burners, or in blowpipes, pressure gas is better, and an engine worked by suction gas develops a rather lower maximum power than with pressure gas. In considering the two types of plant for engine work, the general conclusions are: A suction plant costs less and occupies less ground space, but the gas made in it is not so strong as in the older form of pressure plant, and in some cases this is important. The fuel consumption per h.p.-hour and the labour required are the same in both types of plant, provided the steam required for the pressure gas is raised without an independent boiler. The consumption of water is the same in both types. Where there are several engines to serve, the gas piping is simplified and its cost reduced when the gas is taken from a small gasholder, instead of from several suction plants. In some cases the pressure type is better than the suction, in others suction is better than pressure. From the economical point of view, where producer gas is used for heating work instead of ordinary town gas, there is usually a saving of 50 to 60 per cent. With engines the consumption of anthracite is guaranteed not to exceed 1 lb. per b.h.p.-hour (under full or three-quarter loads) in both types of plant. Gas coke is also used, but its consumption is a little higher. For large furnace work non-caking bituminous coal is almost invariably used, and in some cases this kind of coal is also used for engine work.

3. *Suction Gas Producers.*[1] *By* P. W. Robson.

4. *The Study of Breakages.*[2] *By* Walter Rosenhain, *B.A., B.C.E.*

The importance of the thorough investigation of failures or breakages occurring in engineering practice was dwelt upon in the first part of the paper, more particularly on the ground that such cases serve to show where our existing knowledge and experience are at fault. Manufacturers of materials of engineering construction sometimes shrink from full investigation of failures, but it is frequently found that the failure arose from causes other than inherently bad

[1] Published in *Engineering*, September 11. [2] *Ibid.*

material. The results of such investigations tend, further, to place our specifications upon a sounder basis, and at times to remove unnecessary restrictions from manufacturers.

The principal causes of engineering breakages were classified in three groups —as arising from defects inherent in the material, defects produced during the process of manufacture of the machine or structure, and defects arising during the life of the finished object. Some of the more important cases, such as impure material, metal which has been burnt or overheated, badly forged or annealed, or subjected to improper mechanical treatment, are referred to, and the manner in which these factors can be traced by subsequent investigation are indicated. In illustration of the principles thus laid down the investigation of four typical cases of breakage as carried out by the engineering and metallurgical departments of the National Physical Laboratory were described. In three of these cases, viz., those of a large gun-tube, of a locomotive crank-pin, and of a large shaft, the full text of the Laboratory reports was reproduced, with some additional comments; the fourth case—that of the failure of a boiler-plate—was only referred to as having been already fully published.

In the case of the large gun-tube, which fissured after an unduly short service, mechanical tests show signs of weakness, and the microscopic evidence leads to the conclusion that the failure was due to the contamination of the steel with an excessive amount of slag enclosures. The boiler-plate just mentioned was found to have failed because it was exposed to unduly severe local deformation during the process of construction. The locomotive crank-pin was found to consist of satisfactory steel which had been case-hardened and subsequently quenched. The microscopic evidence showed that the hardening process employed had been too severe, and had resulted in the formation of a number of hardening cracks, some of which had extended through the entire mass of metal under the working stresses. In the case of the large shaft (12 inches in diameter) the failure was found to be due to the fact that while the exterior of the shaft, for a depth of about an inch, consisted of fairly satisfactory material, the interior of the steel showed a very coarse, weak structure, possessing very unsatisfactory mechanical properties. The failure is in this case regarded as due, in all probability, to insufficient forging of the steel during the manufacture of the shaft.

In conclusion it was claimed that modern methods of investigation, if completely carried out under favourable conditions, have a considerable prospect of success in arriving at the cause of a given breakage. The favourable conditions principally insisted upon are the fullest possible information as to all relevant circumstances and the careful preservation of all portions of the fractured part from rust and dirt.

5. *The Electrical Conductivity of certain Light Aluminium Alloys as affected by Exposure to London Atmosphere.*[1] *By* E. Wilson.

TUESDAY, SEPTEMBER 8.

The following Papers were read:—

1. *The Laws of Flight.*[2] *By* F. W. Lanchester.

The Theory of Sustentation.

The law of the pressure reaction for speeds such as may be usefully employed in aërial flight has been established experimentally, and is:—

(1) *On a body of stated geometrical form in given presentation the pressure*

[1] Published in the *Electrician*, September 11.
[2] Published in *Engineering*, September 25.

reaction varies approximately as the square of the velocity, and as the square of the linear dimension.

The theoretical justification of this law is that the viscosity and elasticity of the fluid as quantities of which the resistance is a function, are without sensible influence. This is approximately true, first, concerning viscosity, so long as the product of the linear size and velocity of the body is greater than a certain minimum value; and secondly, as to elasticity, provided that the velocity does not approach too nearly the velocity of sound. In aërial flight as practised by birds or man neither of these limitations applies, so that the V-square law may be accepted as applicable. There is some correction required in regard to *skin-friction*; in resistance of this kind it would appear that the index is somewhat less than 2, though how much at present we do not know.

In the relations of the pressure reaction on *planes at small angles* there is a law of great utility to be deduced from experiment, namely,

(2) *For a given velocity the pressure varies directly as the angle.*

This law only applies to the *small angle*, i.e., to one which, expressed in radians, the angle, its sine, and its tangent, are sensibly equal to one another. The law further does not apply to planes in *apteroid aspect,* in the extreme case of which the sine-square law of Newton can be shown to apply; neither of these limitations seriously affects the validity of the law in relation to aërial flight.

A theory founded on the *hypothesis of constant sweep*—that is, upon the assumption of a layer of air of defined thickness uniformly handled by the aëroplane—gives results in agreement with these two laws, but with a defect in the constant by which the quantities are related. This defect is accounted for and the theory is rectified by taking into account the cyclic component in the periptery; by this extension of the initial hypothesis complete harmony is established between theory and experiment.

The two laws so far established result in the fact discovered by Wenham and rediscovered by Langley, that neglecting skin-friction and other direct resistance the power expenditure decreases when the velocity is increased, and the law of frictionless flight is established.

(3) *Neglecting skin-friction and other direct resistance, the h.p. varies inversely as* V ; *or the resistance to flight varies inversely as* V^2.

The modifying influence of skin-friction and of other resistances varying *directly* as V^2 results in the following laws, the proofs of which are given in the author's 'Aërial Flight,' vol. i., *Aërodynamics.*

(4) *The total resistance to flight is least when the resistance due to aërodynamic support* $\left(\propto \frac{1}{V^2}\right)$ *is equal to the direct resistance* $(\propto V^2)$; *hence this is the condition of greatest range on given fuel-supply.*

(5) *The flight will be sustained for the longest time on a given supply of energy when the resistance due to aërodynamic support is three times the direct resistance.*

(6) *The speed of greatest range is* $\frac{1}{\sqrt[4]{3}}$ $(=1{\cdot}315)$ *times the speed of least power.*

(7) *Neglecting 'body resistance' for aërodromes or aërodones designed for least resistance, the resistance is independent of the velocity of flight.* In other words, *the gliding angle is constant, or the power varies directly as the velocity of flight.*

Cor. *When body resistance is present the total resistance consists of two parts, one of which varies as the velocity squared and the other of which is constant.*

(8) That, consequent on laws 4 and 5, there are best values of angle β (the angle of an aëroplane to the line of flight, or the angle of trail of a pterygoid aërofoil), and of the P/V^2 relation, that correspond to the condition of least resistance. These, tabulated from theory, are found to be in harmony with experience.

The Theory of Stability.

An aërodone or aërodrome may be constructed to possess automatic stability without any *special mechanism* for the maintenance of equilibrium. The natural flight path is of undulating form, the varieties of flight path obtainable being demonstrated both by theory and by experiment, plottings of these curves being given.

An extension of the theory gives an equation, termed by the author the '*equation of stability*,' and it is shown experimentally that this equation gives the limiting proportions of an aërodone of stable flight path.

A final consequence of the theory of stability gives the important fact that for any given design of aërodone or flying machine there is a minimum velocity of stable flight, and that the larger the machine the higher this minimum velocity becomes. For a man-bearing machine it is probably over 30 miles per hour, and in order that a sufficient margin of automatic stability should be provided, the flight velocity should be but little short of 40 m.h.

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2. *The Causes of Wear in Motor Vehicle Machinery.*[1] *By* F. H. Royce.

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3. *Clock-driving Mechanism of Equatorials.*[2] *By* Sir Howard Grubb, *F.R.S.*

The ordinary driving clock for an equatorial generally consists of some form of frictional governor, the best being capable of keeping the rate within about one-fourth to one-fifth per cent., which suffices for all ordinary observing or micrometrical purposes; but for photographic work not only is a higher degree of perfection required but the conditions to be fulfilled are somewhat different.

All frictional governors tend to correct any error in rate which may from one cause or another have occurred; but in the case of instruments used for photographic purposes it is necessary not only that the rate be corrected, but that the error which has crept in owing to difference of rate having occurred shall be completely wiped out, in order that the star images may be brought back to precisely the same position on the photographic plate which they occupied before the error occurred.

In order to effect this an independent free pendulum is used, controlling at every second the rate of the uniform motion clock.

In the original form of this electrical control, devised by the author, and used for the instruments employed in the International Stellar Photographic Survey, the apparatus for effecting this control consisted of three portions, viz., the detector, the distributor, and a pair of correctors for accelerating or retarding, as occasion might require, particulars of which are described in the paper.

This arrangement produced very perfect results, but was necessarily somewhat complicated, and required very careful adjustment.

In this paper the author described a modified and simplified form of this control, in which the distributor is altogether dispensed with, the complication very much reduced, and the adjustments simpler.

It is not claimed that this apparatus gives more perfect results than the original form of control, provided that this latter be in perfect adjustment; but it has been found simpler to work, and gives equally good results, with less liability to go out of adjustment.

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[1] Published in *Engineering*, September 18.

[2] Reported fully, with illustrations, in *Engineering*, September 18.

WEDNESDAY, SEPTEMBER 9

The following Papers were read:—

1. *Experiments on Rotating Discs.*[1] *By* JOHN BROWN, *F.R.S.*, *and* MAURICE F. FITZGERALD, *B.A.*

The authors began by referring to the difficulty of the mathematical analysis of the elastic deformation, under centrifugal stress, of rapidly revolving discs, particularly when formed with a central hole, surrounded by a thick boss, gradually reduced outwards to a thin edge by an arbitrary curve, and mentioned the investigations of Mr. Chree and Mr. F. Purser of the cases of cylinders and ellipsoids. The authors' experiments were described as made for the purpose of finding out whether approximate formulæ, such as have been given for cases in practice in such works as that of Stodola on steam-turbines, are sufficiently nearly correct for practical purposes. Two discs, made of red rubber, weighing 72 lb. per cubic foot, were tested. The discs were both 12 inches external diameter. One was solid, $\frac{1}{2}$ inch thick at edge, 2 inches at the centre, its surfaces being two flat cones. The other was $\frac{5}{8}$ inch thick at edge, in its centre was a hole $1\frac{1}{2}$ inch diameter, surrounded by a boss, with flat ends, $2\frac{1}{2}$ inches diameter and 3 inches thick, the surfaces between the edges of the boss and disc being shaped to hollow hyperbolic curves. The discs were suspended from the end of the shaft of a small motor, placed with its axis vertical, and circles drawn on the faces, previously painted white, while spinning. Photographs being taken of the discs while spinning and when at rest, the strains at different radii were found by comparison of the photographs, and plotted as curves, shown by lantern slides. The results were compared with those of approximate formulæ. In the case of the solid disc the difference between the speeds causing a given strain, as calculated and as observed, amounts to about 20 per cent., and may, considering the imperfect elasticity of indiarubber, be considered a fair enough approximation; but in the case of the other disc, though the formula gives a tolerably fair idea of the shape of the curve of strains, its error as to the actual magnitude of the speed causing a given strain is so great, being near 400 per cent., as to lead to the conclusion that the formula could not be trusted for practical purposes.

2. *General Urban and Inter-urban Transportation and Railless Electric Traction.*[2] *By* F. DOUGLAS FOX, *M.Inst.C.E.*

3. *The Strength of Solid Cylindrical Round-ended Columns.*[3] *By* Professor W. E. LILLY, *M.A.*, *D.Sc.*

In some previous papers[4] by the author the importance of secondary flexure and its influence on the strength of columns was demonstrated. The result of these researches led to a revision of the formulæ at present in use for the design of columns. It was shown that some provision requires to be made for the wave deformation due to secondary flexure, which depends upon the thickness and the figure or shape of the cross-section of the column. A modified formula based

[1] Reported fully, with illustrations, in *Engineering*, September 18.

[2] Published in *Engineering*, September 18.

[3] Published in *Page's Magazine*, September 18.

[4] References to previous papers: 'The Strength of Columns,' Proceedings of the Institution of Mechanical Engineers, June 1905; 'The Economic Design of Columns,' Proceedings of the Institution of Civil Engineers of Ireland, March 1907; 'The Design of Struts,' *Engineering*, January 10, 1908.

upon the experimental work and theory was then given which took into consideration this variable. The object in view in the present paper was the determination of the constants to be used in the formulæ for the design of solid round-ended columns. A series of experiments were carried out on columns of cast-tool steel, Bessemer steel, mild-steel shafting, rolled and annealed, wrought iron, and cast iron. The results obtained are recorded on three diagrams, on which are plotted five curves obtained from the experiments, together with the stress-strain diagrams from the different materials and a series of curves plotted to the formulæ adopted.

Some interesting results have been obtained as to the effect of the ductility of the material, its strength at the yield point, and Young's modulus of elasticity upon the strength of solid columns. A comparison is then given of the Rankine-Gordon and other formulæ. The constants to be used and as adopted from the experiments are then discussed.

Section H.—ANTHROPOLOGY.

President of the Section.—Professor William Ridgeway, M.A., LL.D., Litt.D., F.B.A.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address:—

The Application of Zoological Laws to Man.

Thirty years ago in this very city I heard for the first time a Presidential Address at the British Association, and I was singularly fortunate in entering on my novitiate. I had the privilege of hearing Professor Huxley deliver his Presidential Address to the embryo of that Section over which I, a very unworthy successor, have this day the honour to preside. On that occasion Huxley dealt almost exclusively with the physical evolution of man, and the Neanderthal skull played an important part in his discourse. The anthropologists of that day and since have severely criticised, and rightly so, the old teleological doctrine that everything except man himself had been created for man's use, and they emphatically enunciated the doctrine that man himself has been evolved under the same laws as every other animal. Yet the anthropologists themselves have not always carried out in practice their own principles to their logical conclusions. To-day I shall attempt to show that the chief errors which impede the scientific study of man which lead to the maladministration of alien races, and which beget blunders of the gravest issue in our own social legislation, are due in the main to man's pride in shutting his eyes to the fact that he is controlled by the same laws as the rest of the animal kingdom.

I. Let us first consider some of the chief problems which at present are being debated by the physical anthropologists. Foremost in importance of these is the stratification of populations in Europe. It has generally been held as an article of faith that Europe was first peopled by a non-Aryan race. Of course it is impossible for us to say what were the physical characteristics of palæolithic man, but when we come to neolithic man the problem becomes less hopeless. It has been generally held that the first neolithic men in Europe, whether they were descended or not from their palæolithic predecessors, had long skulls, but were not Aryan; that later on a migration of short-skulled people from Asia passed along Central Europe and into France, becoming what is commonly termed the Alpine, by some the Ligurian, by others the Celtic race; that later these two primitive non-Aryan races were overrun by the Aryans, who, when these theories were first started, were universally considered to have come from the Hindu Kush, but are now generally believed, as held by Latham, to have originated in Upper Central Europe. Yet, although the view respecting the cradle of the Aryans has changed, anthropologists have not seen the important bearing that it has upon the problem of neolithic man. The Aryans are generally held to have had a blonde complexion.

As our discussion must from its nature concern itself with questions of race, let us first examine the criteria by which anthropologists distinguish one race from another. If you ask an anthropologist how he distinguishes an Aryan from a non-Aryan race, he will tell you that he relies on three main tests: (*a*) the colour of the skin, hair, and eyes; (*b*) the shape of the skull and certain other osteological characteristics; and (*c*) the system of descent through males. Formerly language was included in the tests of race, but when it was pointed out that the Negroes of Jamaica speak English, those of Louisiana French, henceforward it was assumed that one race can embrace the language of another with the greatest ease. Yet it may turn out, after all, that language was too hastily expelled from the criteria of race. On the other hand, we may find that too implicit faith has been placed on the three criteria of cranial characteristics, pigmentation, and law of succession.

(*a*) As it is assumed that all Aryans were blonde and traced descent through males, so it is held that all Europeans, who are dark-complexioned, and whose forefathers traced descent through women, are non-Aryan in race, and that, although they now in almost every case speak an Aryan tongue, this is not their primitive speech, but simply that learned from their Aryan conquerors. According to this orthodox view, the dark-skinned inhabitants of Italy, Spain, and Greece are all non-Aryan, and all have borrowed the language of their masters, whilst of course the same is held respecting the melanochrous population of France and of the British Isles. Ever since Professor Sergi comprehended under what he terms the 'Eurafrican species' all the dark-complexioned peoples of Southern and Western Europe, as well as the Semitic and Hamitic peoples of Western Asia and Northern Africa, the doctrine that the dark-skinned peoples of Europe once spoke a non-Aryan tongue or tongues is supposed to have been finally established. But under his Eurafrican species Sergi includes the blonde race of Northern Europe who speak Aryan languages along with the dark races who speak non-Aryan tongues. It is argued that as all the dark-skinned peoples on the north side of the Mediterranean belong by their physical type to the same original stock as the Semites and Hamites, they must likewise have spoken non-Aryan languages. Yet it might as well be maintained that the Finns, who speak a non-Aryan tongue, and the Scandinavians, who speak an Aryan, were originally all of one stock, because both races are blonde.

This doctrine of a Mediterranean race depends upon the tacit assumption made by the physical anthropologists that identity or similarity of type means identity of race. Yet this assumption does not bear the test of scientific examination, for it assumes that only those who are sprung from a common stock can be similar in physical structure and coloration, and it leaves altogether out of sight the effects of environment in changing racial types, and that, too, in no long time. The change in the type of the American of New England from that of his English ancestor and his approximation to the hatchet face and thin scraggy beard of the Red Indian have long been remarked, whilst the Boers of South Africa, in less than 150 years, have quite lost the old Dutch build, and become a tall weedy race. The effects of climatic conditions are very patent amongst the native peoples of the New World. The Iroquois of the temperate parts (lat. 40°–45°) of North America were a tall rather light-complexioned race, but as we keep moving south and approach the equator, their kindred tribes grow somewhat darker in complexion and more feeble in physique, except where they live at a considerable altitude, for of course altitude acts in the same way as latitude. When once we pass below the equator the physique keeps steadily improving until we come to the Pampas Indians, a vigorous race who defied all the efforts of the Spaniards to subdue them; and finally we meet the Patagonians (lat. 40°–53°), a fine, tall, light-complexioned race, who form in the south the counterpart of the Iroquois and their closely allied tribes in the north.

The same law, as is well known, can be seen at work in Europe. Starting from the Mediterranean, we meet in the lower parts a melanochrous race; but gradually, as we advance upwards, the population as a whole is growing less dark, until finally, along the shores of the Baltic, we meet the tallest and most light-complexioned race in the world. Of course it has been explained that the change in pigmentation, as we advance from south to north, is due to the varying proportions in the admixture of the blonde race of the north with the melanochrous of the south. But it is difficult to believe that the movements up or down of the people from the southern side of the Alps, or of those from the shores of the Baltic, have been so nicely proportioned as to give the general steady change from north to south in coloration without the aid of some other force. The case of America, which I have just cited, is in itself enough to raise a suspicion that climatic influences are at work all the time, and that environment is in reality the chief factor in the variation of both stature and pigmentation from the Mediterranean to the Baltic. The white race of the north is of the same proximate ancestry as the dark-complexioned peoples of the northern shores of the Mediterranean. I have already argued elsewhere that, as the ice-sheet receded, mankind kept pressing further north, and gradually under changed climatic conditions the type changed from area to area, and they all still continued to speak the same Indo-European tongue, but with dialectic variations, these also being no doubt due to the physical changes in the vocal organs produced by environment.

If we turn from man to the other animals we find a complete demonstration of this doctrine. For instance, the conditions which have produced a blonde race on the Baltic have probably produced the white hare, white bears, and the tendency in the stoat and the ptarmigan to turn white in winter, whilst in the same regions of Europe and Asia the indigenous horses were of a dun colour, who not only turned white in winter but had a great tendency to turn white altogether. It may be objected that the Lapps and Eskimo are not tall and blonde, but on the contrary short and dark; but they live within the arctic circle in regions where the sun does not shine at all for a great part of the year, and consequently they are quite outside the conditions of environment under which the tall blonde race of North Germany has long dwelt. Of course, in dealing with man we are always confronted with the difficulties arising from his migrations; but if we can find a family of lower animals who cannot be said to have thus migrated, and who show the effects of environment, we shall be able to argue powerfully from analogy.

The horse family supplies the example required. If we follow it from Northern Asia to the Cape of Good Hope, we shall find that every belt has its own particular type, changes in osteology as well as in coloration taking place from region to region. First we meet the old dun horse, with its tendency to become white, the best European examples of which were probably the now extinct ponies of the Lofoden Isles. In Asia, Prejvalsky's horse is the best living instance—a dun-coloured animal with little trace of stripes. Bordering on the Prejvalsky horse or true tarpan come the Asiatic asses: first the dzeggetai of Mongolia, a fawn-coloured animal, the under-parts being Isabella-coloured; then comes the kiang of the Upper Indus valley, seldom found at a lower altitude than 10,000 feet, rufous brown with white under parts, whilst, as might be expected from its mountain habitat, its hind-quarters are much more developed in length and strength than in the asses of the plains. The *Onager indicus*, *onager* and *hemippus* are found in all the great plains of the Punjab, Afghanistan, Western India, Baluchistan, Persia, and Syria, whilst a few are said to survive in South Arabia. All these are lighter in colour than the kiang, the typical onager being a white animal with yellow blotches on the side, neck, and head. All the Asiatic asses are distinguished by the absence of any shoulder stripe, though they occasionally show traces of stripes on the lower parts of the legs. The southern Asiatic asses just described in their greyer colour and smaller hoofs approximate to the wild asses of Africa, especially to those of Somaliland, whilst it is maintained that in their cry, as well as in their colour, the kiang and dzeggetai come closer to the horse, whose next neighbours they are.

Passing to Africa, we find the ass of Nubia and Abyssinia showing a shoulder stripe, and frequently with very strongly defined narrow stripes on the legs, the ears being longer than those of the onager. But in closer proximity to South-Western Asia comes the Somali ass, which differs from those of Nubia and

Abyssinia by being greyer in colour, by the entire absence of shoulder stripes, and by smaller ears, in all which characteristics it comes closer to its neighbours on the Asiatic side than it does to its relations in Abyssinia and Nubia.

Next we meet the zebras. First comes the magnificent Grévy zebra of Somaliland, Shoa, and British East Africa. It is completely striped down to its hoofs, but the coloration of the specimens from Shoa differs from that of those from Somaliland, and from those of British East Africa. The Grévy zebra has its hoofs rounded in front like those of a horse, but its ears are more like its neighbours the asses than those of any other zebra.

In the region north of the river Tana the Burchelline group of zebras overlaps the Grévy, and though it differs essentially in form, habits, and shape of its hoofs from the Grévy some of those in the neighbourhood of Lake Barringo show grid-iron markings on the croup like those on the Grévy zebra, whilst, like the latter, they also possess functional premolars.

All the zebras of the equatorial regions are striped to the hoofs, but when we reach the Transvaal, the Burchelline zebra, known as Chapman's, is divesting itself of stripes on its legs, whilst the ground colour is getting less white and the stripes less black. Further south the true Burchell zebra of the Orange River has completely lost the stripes on its legs and under-surface, its general colouring being pale yellowish brown, the stripes being dark brown or nearly black. South of the Orange River the now extinct quagga of Cape Colony had not only begun to lose the stripes of its under-part and on the hind-quarters, but in Daniell's specimen they only survived on the neck as far as the withers, the animal having its upper surface bay and a tail like that of a horse, whilst all specimens of quagga show a rounded hoof like that of a horse.

In the quagga of 30° to 32° S. we have practically a bay horse corresponding to the bay Libyan horse of lat. 30°–32° N.

But the production of such variations in colour do not require great differences in latitude. On the contrary, from a study of a series of skins of zebras shot for me in British East Africa, each of which is from a known locality and from a known altitude, there can be no doubt that such variations in colour are found from district to district within a comparatively small area.

In addition to the two species of zebra already mentioned, there is the mountain zebra, formerly extremely common in the mountainous parts of Cape Colony and Natal, though now nearly extinct in that area. Its hind legs, as might naturally have been expected from its habitat, are more developed than those of the other zebras, just as these same limbs are also more developed in the kiang of the Himalayas than in any other ass.

With these facts before us, there can be no doubt that environment is a most potent factor not only in coloration, but also in osteology. No less certain is it that environment is capable of producing changes in animal types with great rapidity. Thus, although it is an historical fact that there were no horses in Java in 1346, and it is known that the ponies now there are descended from those brought in by the Arabs, yet within five centuries there has arisen a race of ponies (often striped) some of which are not more than two feet high. Darwin himself has given other examples of the rapid change in structure of horses when transferred from one environment to another, as for instance when Pampas horses are brought up into the Andes.

Another good example is that of the now familiar Basuto ponies. Up to 1846 the Basutos did not possess a single horse, those of them who went down and worked for the Boers of the Orange River usually taking their pay in cattle. At the date mentioned some of them began to take horses instead. These horses were of the ordinary mixed colonial kinds, and we may be sure that the Boers did not let the Basutos have picked specimens. The Basutos turned these horses out on their mountains, where living under perfectly natural conditions their posterity within less than forty years had settled down into a well-defined type of mountain pony.

Nor is it only in the horse family that we meet with examples of the force of environment. The tiger extends from the Indian Ocean, through China up to

Corea, but the tiger of Corea is a very different animal from that of Bengal. Instead of the short hair of the Indian tiger the Corean has clothed himself with a robe of dense long fur to withstand the rigours of the north. It is not unlikely that if we had a sufficient number of skins from known localities we could trace the change in the tiger from latitude to latitude, just as I have shown in the case of the Equidae.

Now whilst there is certainly a general physical type common to all the peoples round the Mediterranean, it by no means follows that all those peoples are from the same original stock. On the contrary, the analogy from man in other parts of the world, as well as that of the Equidae, suggest that the resemblance between the Berbers, who speak Hamitic, the Greeks who speak Aryan, and the Jews and Arabs who spoke Semitic, is simply due to the fact that those peoples from having long dwelt under practically similar conditions in the Mediterranean basin, have gradually acquired that physical similarity which has led Sergi to the assumption that they have a proximate common ancestry, and that they accordingly form but a single race.

Nor is there any lack of instances of convergence of type under similar conditions in the case of the lower animals. We saw that the asses of South-Western Asia approximate in colour to the asses of North-East Africa, and in respect of the size of the ears and absence of shoulder-stripe, more especially to the nearest of these, the ass of Somaliland. Yet it does not follow that they are more closely related to the Somali ass than they are to their own next neighbours, the kiang. On the contrary, it is much more likely that the Somali ass is closely related to those of Abyssinia, and that the South-Western Asiatic asses are closely related to the kiang. The approximation in colour, absence of shoulder-stripe, and size of the ears between the asses of Somaliland and those of South-Western Asia must rather be explained by a convergence of types under the somewhat similar climatic conditions of Somaliland and the nearest parts of South-Western Asia. Again, though there are very strong specific differences between the Grévy and Burchelline zebras met in the neighbourhood of Lake Barringo, there is a curious approximation not only in marking but also in the teeth between these two species, which is best accounted for by supposing that it is the outcome of similar environment. It may be said that this approximation may be due to the interbreeding of the two species of zebras in the region where they overlap. This, in itself a most unlikely contingency from all that is known of the habits of wild species, certainly cannot be alleged in the case of the convergence in type between the asses of South-Western Asia and the Somali ass, since they are separated by the Red Sea and the Persian Gulf.

Again, the representative of the crocodile family in the Ganges is distinguished by the extreme elongation of the head and jaws, whilst the same elongation of the head is equally characteristic of the representative of the dolphin family found in the same waters. Again, all through the Indian Ocean wherever any family of crabs have become inhabitants of coralline sands its members have long legs. Again, it has long been noticed that in Cutch all the larger animals have a tendency to become a sandy colour, whilst in certain areas of South America insects, no matter to what family they belong, have a tendency to one common aspect.

It may of course be said that the changes in colour of the horse family, tigers, and insects are for 'protective' reasons. But the case of the horse family alone is sufficient to dispose of this objection. The kiang of the Himalaya had no dangerous enemy until man was armed with a rifle. In Africa the zebras have had only two formidable foes—man and the lion. It is asserted by the most experienced hunters that the gaudy livery of the zebra makes him conspicuous from afar, whether he is on the mountain, on the plain, or in the shade of a tree. His brilliant colour therefore really exposes him to man. But it will be said that it is well adapted to conceal him at night, at which time the lion seeks his prey. Yet as the best authorities hold that the lion hunts entirely by scent, the coloration of the zebra affords him no protection against his inveterate foe.

I have shown that in horses the colours—such as bay, black, grey, and white—

accompany certain well-defined inward qualities. But as black is most certainly not a primitive horse colour, it follows that coat colours may be intimately connected with certain other characteristics quite irrespective of protective colouring. Again, as the variation in the size and shape of the ears and hoofs of the asses and zebras cannot be set down to protective colouring, but must be due to other causes, there is no reason why variations in colour should not be ascribed to similar causes.

The argument based on the analogy of the horse family and the tigers, and on that of the natives of the New World, may be applied to the races of Africa. Next to the Mediterranean lie the Berbers and their Hamitic congeners, who are regarded as part of the Eurafrican species by Sergi and his school. But the Berbers are not all of the typical Mediterranean physique. The blonde Berbers of the highlands of Rif in North-West Morocco and of the Atlas have long been well known. In the region lower down and in Western Tunis the occurrence of the xanthochrous type seems much less frequent, whilst further east it practically disappears.

It is certain that there was a fair-haired element in Libya long before Rome conquered Carthage or the Vandals had passed into the ken of history. Callimachus testifies to the existence of blonde Berbers in the third century B.C. We may hold, then, with Sergi and others that the blonde element in the Berbers is not a survival from invasions of Vandals or Goths, or from Roman colonists, but that they rather owe their fair complexions and light-coloured eyes to the circumstance that they were cradled in a cool mountainous region, and not along the low-lying border of the Mediterranean like their dark-coloured relations whose language and customs they share.

If, then, some of those who speak Hamitic are fair, and have been fair for centuries before Christ, as Sergi himself admits, whilst others are dark, there is no reason why some of the peoples who speak Aryan might not be dark whilst others are blonde.

The Berbers and their Hamitic congeners shade off on the south into other peoples, but this is not altogether due to intermarriage, as is commonly held, for it is more probably to be explained as due in a large part to climatic conditions. The Bantus, who are said to have originated in the Galla country and to have spread thence, are now regarded by the chief authorities as the result of an intermixture of Hamites and Negroes. But, on the grounds I have already stated, it is more rational to regard them as having been evolved in the area lying between the Hamitic peoples on the north and the Negroes on the south, just as we have corresponding types of the horse family in Nubia and Abyssinia and in the equatorial regions. The same hypothesis also explains the existence of those cattle-keeping tribes which lie west of the Nile stretching across Northern Nigeria, who border on the Berbers, but yet differ from them, and border also on the Negroes, but differ from them likewise. South of these tribes come the Negroes, the true children of the equator. The Bantu is able to live in elevated equatorial areas, and he has burst his way down to the sub-tropical and temperate parts of south Africa, where he especially flourishes in the highlands, thus showing that his race was originally evolved under similar conditions. The Bantu found in the South the Hottentots, who are especially distinguished by steatopygy, a feature which has led some to identify them with the primitive steatopygous race supposed to have once lived in Southern Europe, Malta, and North Africa, and to have left evidence of their characteristic in their representations of themselves. But, granting that such a race once lived in North Africa and Southern Europe, there is really no more reason for supposing that they and the Hottentots formed one and the same race than there is for assuming that Daniell's quagga, which was practically a bay horse, was proximately akin to the bay horse of North Africa. The occurrence of steatopygy in two areas so wide apart is not due to an ethnical migration, but rather to similar climatic conditions producing similar characteristics.

As some anthropologists so commonly explain the origin of races such as the Bantus by intermarriage, it may be well to see whether intermarriage between two races, one of which is an invader, is likely to produce a permanent effect upon the general physique of a whole community. I have shown elsewhere that the many invasions of fair-haired races into the three southern peninsulas of Europe and into the Aegean islands have left no permanent trace on the population. It is a matter of common knowledge that the offspring of British and native parents in India have a constant tendency to die out. The same undoubtedly holds true for the offspring of British soldiers serving in Egypt, the Soudan, and West Africa. The native race always reasserts itself. In America the Spanish blood has died out, or is dying out, everywhere except in the temperate regions of Chile, Quito, and Argentina, where the descendants of the Spanish settlers thrive in a climate very analogous to that of Spain. In the Southern States of North America the whites cannot flourish, and only just manage to survive. On the other hand the descendants of the Negro slaves imported into Brazil, the West Indies, and the Southern States of North America thrive and multiply with extraordinary vigour; a fact doubtless due to their race having been evolved under similar conditions in equatorial Africa.

Even from the evidence already to hand there is high probability that intermarriage can do little to form a new race unless the parents on both sides are of races evolved in similar environments.

I have already pointed out that although the fair-haired race of Upper Europe has age after age kept pouring over the Alps into Italy and the other southern peninsulas, and have constantly intermixed with the indigenous populations, it is only in the upper part of Italy that the blonde race is able to hold its own. In Italy the xanthochrous race in ancient times as to-day had its maximum along the Alps, and gradually dwindled towards the south until the melanochrous race stood practically alone in the lower part of the peninsula. So too in the Balkan, whilst the fair-haired element was at its maximum along the Alps and the Danube, southwards the melanochrous becomes more and more completely dominant, as it practically is to-day in the lower part of the peninsula.

(*b*) In the Alpine regions there has been from Neolithic times a brachycephalic race, also found in Central France and in the British Isles, whither it is supposed to have come in the Bronze age. It has been a fundamental article of faith with Sergi and others that this round-headed race came from Asia, the home of brachycephalism. It is Mongolian according to most, and spoke a non-Aryan language; but Sergi regards it as Aryan, thus reverting to the old doctrine, which made the Aryans come from Central Asia, and he assumes that these invaders imposed their language both on the aborigines of Italy, such as the Ligurians, and on the blonde race of Northern Europe; but we shall soon see that this assumption has no base. Now, as these folk dwelt in the region where we find the Ligurians of historical times, others have argued that the Ligurians were a non-Aryan people from Asia. But it is impossible to find any hard-and-fast lines between the Alpine race and the peoples north and south of it in culture and sociology. For that reason when treating of the people of the Alps in my 'Early Age of Greece' I did not take any account of the difference in cranial measurements. In 1906, at the British Association, I maintained that this difference of skull type did not mean any racial difference, and on the analogy of the changes in the osteology of the Equidae I urged that the roundness of the skulls was simply due to environment, as the horses of the Pampas when brought up into the mountainous regions of Chile and Peru rapidly change their physical type. Physical anthropologists have already maintained that the round head of the Mongolian has been developed in the high altitude of the Altai. If that be so, there is no reason why a similar phenomenon should not have taken place in the Alpine region, in Albania, Anatolia, and wherever else in mountain areas brachycephaly has been found in more than sporadic examples, which of course may well be due to migrations or importation of slaves. But I am far from suggesting that altitude is the only cause of brachycephaly.

The evidence then, as far as it goes, points to the same conclusion as that to which we came as regards pigmentation, and it may eventually be proved that just as each area has its own type of coloration, so also has it its own osteological character. In support of this I may point out that recently Dr. William Wright, Hunterian lecturer, has come to the conclusion from his craniological investigations that the brachycephalic Alpine race was evolved on European soil, whilst Dr. C. S. Myers has been led by his researches on Egyptian skulls to conclude that, 'in spite of the various infiltrations of foreign blood in the past, modern Egypt contains a homogeneous population which gradually shifts its average character as we proceed southwards from the shores of the Mediterranean to Nubia beyond the First Cataract.'

It is not impossible that Alpine environment may have acted upon the shape of the skull of the ox as well as that of man. We know from the examination of the fauna of the Lake dwellings of Switzerland that the Celtic ox (*Bos longifrons*) was there the common type, and its descendants still continue to be the typical breed along the Alpine chain. This ox is characterised by its strongly developed occipital region and its small horns curved forward and inward. As it differs so essentially from the urus (*Bos primigenius*) and from the long-horned cattle of the Mediterranean lands, it seems not unlikely that the peculiar cranial formation may have been evolved under mountainous environment.

It is now clear that differences in the shape of the skull and in the colour of the skin, hair, and eyes cannot be at all implicitly relied on as criteria of race. The defenders of the non-Aryan character of the dark races of Greece, Italy, Spain, France, and the British Isles have now to depend on two arguments only, one of which is linguistic, the other sociological. It is admitted that it is very difficult to point to any non-Aryan survivals in the vocabularies of the languages of these countries, and it is also admitted that in them all the tense system of the Aryans has been taken over in its entirety. Neither Kretschmer nor anyone else has ventured to affirm that there is any survival of non-Aryan syntactical forms in Greek, the language of all others in which the Ayran tense system is found in its greatest delicacy and perfection. But we know that in all cases where an Aryan language has without doubt been adopted by a non-Aryan folk the tense system is invariably broken up. No better example than this is needed than ordinary 'pigeon' English. So difficult is it for the defenders of the non-Aryan theory of the origin of the aborigines of Greece to maintain their position that one of the latest, Professor Burrows, has to rely on certain supposed syntactical survivals of a non-Aryan language which Sir John Rhys believes that he has found in Welsh and Irish and in the remarkable resemblance which Professor Morris Jones thinks that he has traced between the syntax of those languages and that of Berber and ancient Egyptian.

Yet when we examine the evidence on which Sir John Rhys relies, it turns out to be only three Welsh and Cornish oghams, written not in pure Celtic, but in dog Latin, and also two Irish oghams, which show a looseness in the use of the genitive suffix at a time when final syllables were dropping out of use in Irish. Sir John Rhys supposes that the non-Aryan inhabitants of these islands derived their Gaelic speech from a people whom he terms Celticans, who spoke Goidelic, and who were followed by the Brythons, who found the aborigines already Celticised. Professor Morris Jones freely admits that the aborigines must have borrowed the full Aryan tense system, a fact in itself sufficient, from what I have already said, to arouse grave suspicions as to the validity of any arguments based on supposed fundamental grammatical differences. But this supposed taking over of the full Aryan tense system by the non-Aryan aborigines of these islands is rendered all the more miraculous from the circumstance that Sir John Rhys holds that his Celticans who spoke Goidelic 'came over not later than the great movements which took place in the Celtic world of the Continent in the sixth and fifth centuries before our era,' that the Brythons came over to Britain between the time of Pytheas and that of Julius Cæsar,' and that the Brythons were not likely to come into contact on any large scale with the aborigines 'before they had been to a considerable extent Celticised.' It is thus assumed that it was possible for the aborigines to have been so completely Celticised as to have adopted the Aryan tense system, as well as the Aryan vocabulary, in its fulness in the interval between the sixth or fifth century and the second century B.C. Yet English has been the master speech in Britain for many centuries, and that, too, when reading and writing have been commonly practised; yet Gaelic still survives, whilst Welsh not only survives but flourishes. It is therefore simply incredible that such a complete transformation as that postulated could have taken place in three or four centuries in an age when writing and literature can be hardly said to have existed in these islands.

Let us now see under what conditions does one race or people borrow the language of another. Slaves of course take over the language of their masters, but we have to consider (1) the adoption by a conquering people of the language of the conquered, (2) the adoption by a conquered people of that of their conquerors, and (3) the adoption by a people themselves unconquered of the language of their neighbours. Under what conditions do the conquerors adopt the language of the conquered? Ireland affords us at least two certain examples. Cromwell planted large bodies of his English soldiers in Tipperary, but they had no English women, and therefore took as wives the daughters of the land, who spoke the Irish language. From this union resulted a splendid offspring, who spoke chiefly the language of their Irish mothers, and not their fathers' English. So it came to pass that in a single generation the progeny of Cromwell's Puritans were in language as Irish as the purest blooded aboriginal of Munster. Yet this adoption of the Irish language by the great majority of the children of these settlers took place in spite of the effect which the reading of books in English must have exerted to counteract the tendency to adopt the Irish language. Let us go back five hundred years in Irish history and we find exactly the same process going on. The Normans who followed Strongbow into Ireland, like their captain, frequently married native women. It is a matter of common knowledge that the Anglo-Norman settlers in a short time became *Hiberniores ipsis Hibernis.*

These and other examples too numerous to cite here prove that the children of bodies of conquerors who marry the women of the land will have an inevitable tendency to follow their mothers' speech. We may also lay down as a solid factor in the tendency of the conqueror to merge into the conquered the isolation of the conquerors from their original homes and from the great mass of those who speak the same language.

Next we come to the case where the conquerors bring with them some women of their own race. This of course helps to keep their own language alive, as a certain number of the children speak it as their mothers' tongue. But even in these circumstances the invaders are liable to drop their own language and practically adopt that of the natives. Thus the Northmen who settled on the coast of France gradually abandoned their national tongue for French, though modifying dialectically their adopted language. When under the name of Normans they conquered and settled in England, they again adopted the language of the conquered, though modifying the English tongue by many words and phrases brought with them from Normandy, and we have just seen how some of their descendants who settled in Ireland for the third time changed their speech for that of the conquered.

Hitherto all our examples show the adoption by the conquerors of the language of the conquered, even when they bring a certain number of their women with them.

We now come to undoubted cases where the language of the conqueror has been able to get a firm foothold. From the time of the plantation of Ulster, the advance of the English tongue, and consequent decadence of the Irish, has steadily proceeded, for the settlers, unlike Cromwell's Ironsides, brought with them women of their own race and speech. Consequently their children grew up speaking English as their mothers' tongue. Yet even with such a basis the advance of English amongst the Irish has been exceedingly slow. In the glens of Antrim the Irish language still lingers on, whilst in Donegal, Connaught, Kerry, Cork, and Waterford, English has not succeeded in ousting completely the native language, though the former is the language of the national schools, of the newspapers, and of trade.

The story of the establishment of English itself in Britain is just the same as in Ulster. We know from Bede that the Angles who settled in Britain left

Holstein in large bodies, bringing with them their wives and families, and leaving their old homes without inhabitant. Having thus settled in solid masses in the east of Britain, they retained fully their own tongue, impressed it upon their menials, and gradually, as they extended their conquests westward over the island, English became the language of the land. Yet in Wales the ancient speech still flourishes.

We may therefore conclude that the adoption by the conquered of the language of the conqueror, even when it does take place, which is but rarely, is a very slow and tedious process, although every advantage is on the side of the invading tongue, and that when the native speech gets a fair field, as in Wales, the language of the conqueror can make little or no advance.

Only the third possibility now is left—that one people can adopt without conquest the language of another. But no example of such can anywhere be found, although Europe presents numerous instances to the contrary. There can be no stronger case than that of the Swiss Republic, in which peoples with more than four kinds of language combine for national defence and other advantages. Here, if anywhere, we ought to find a gradual adoption by certain cantons of the language of their neighbours. But, far from this being so, the German, French, Roumansch, and Italian cantons rigidly preserve their respective mother-speeches. In the Austro-Hungarian Empire there is no tendency observable on the part of either Magyars or Slavs to adopt German; nay, the very opposite is the case. Again, the Finns have not adopted either Swedish or Russian, though partitioned between their more powerful neighbours.

To sum up, it seems that no nation readily adopts the language of another, even though it be in close ties of friendship; whilst there is still less tendency when national hostility intervenes. Secondly, the adoption of the language of the conqueror by the conquered, except under the most favourable circumstances, is not common, and only takes place by a very gradual process, as is seen in the case of Ireland. Thirdly, there is a strong tendency for the conqueror to adopt the language of the conquered, as was done by the Normans in England, in Ireland, in Sicily, and in Italy; by the Cromwellian settlers in Tipperary, by the Bulgari in Bulgaria, by the Franks in Gaul, by the Lombards in Italy, and by the Visigoths in Spain. There is thus an inevitable tendency for the children to speak their mothers' tongue, and indeed the phrase 'mother-tongue' is based on the fact observed through long ages that the child learns its first words from its mother and thus takes after her in speech. This law, which still holds good in modern days and in civilised communities, must have been far stronger in earlier times in countries where the tie of marriage hardly existed and the child belonged to its mother's and not to its father's tribe, as is still the case in many parts of the world.

In view of these facts we cannot accept Sir John Rhys's hypothesis that when a few bodies of invaders, whom he terms Celticans, passed into Ireland the indigenous supposed non-Aryan race within two centuries completely abandoned its own language, taking over in its entirety the Aryan tense system as well as the Aryan vocabulary of its conquerors.

Now let us turn to Greece, Italy, and Spain. It is admitted that neither Arcadia nor Attica was ever conquered by Acheans or Dorians, yet in both these areas the Greek language existed through all historical time, and in Attica especially the Aryan tense system is found in its highest perfection. The dialect of Arcadia cannot have been taken over from Acheans or Dorians, because it is the same as that of the Cypriotes from Arcadia who settled in Cyprus at least 1100 B.C. It is also very close to the dialect of Pelasgiotis in Thessaly, the home of the aboriginal Pelasgian population, whilst it comes closest of all Greek dialects to that of the ancient Epic. There can therefore be no doubt that Arcadian is no mere bastard lingo, half non-Aryan, half Aryan, but is the genuine speech of the oldest and most unmixed population of Greece, who were undoubtedly a melanochrous race, and who also most certainly had occupied Greece from the Stone age.

The Ligurians, who formed from the Stone age the bottom stratum in all

Upper and Central Italy, are now admitted to have spoken an Aryan language, and I have recently given some reasons for believing that the Latin language is simply the native tongue of the aboriginal Ligurian population of Latium with some admixtures derived from the Italic tribes of Siculi and Sabines. I have also shown that the ancient Iberians, the next neighbours of the Ligurians, used the same forms of place-names as the latter, and that some of the words plainly exhibit Aryan terminations. Thus we may conclude that with the exception of the Basques, who are probably a non-Aryan spurt from North Africa, the melanochrous populations of Spain, Italy, the Balkan Peninsula, France, Britain, Ireland, and Holland have from the first spoken none but an Aryan language.

(*c*) Only one argument is now left to the defenders of the non-Aryan theory. When the study of sociology first sprang up in the last century, it at once became a fundamental doctrine that the Aryans had always been strictly patriarchal, and that polyandry and descent through women was unknown amongst them. Though this view has received many rude shocks in later days, Professor Zimmer argues from it that the indigenous people of Britain and Ireland were non-Aryan.

It is well known from the ancient writers that the Picts were polyandrous and that succession was consequently through females. Again, it is certain, both from the ancient Irish literature and also from statements of external writers, that the Irish were polyandrous, and that they also almost certainly traced descent through women. Accordingly Professor Zimmer infers that the indigenous race was non-Aryan. But McLennan has long since pointed out that descent through women was the ancient law at Athens, and I have just shown that the Athenians and Arcadians, the autochthonous, dark-complexioned people of Greece, never spoke any save an Aryan tongue. Moreover, I have shown elsewhere that the Ligurians, who are now generally admitted to have spoken always an Aryan language, had descent through women, whilst I have also pointed out that there is good evidence that the ancient Latins, who have generally been taken as typical Aryans, had the same system. Again, it is admitted that the ancient Illyrians and dark-complexioned Thracians spoke an Aryan language, which, inasmuch as it differed materially in certain ways from that spoken by their Celtic overlords, must have been aboriginal, whilst I have further given grounds for believing that the ancient Iberians (though not the Basques) were also an Aryan-speaking folk. But there is good evidence that the Illyrians, melanochrous Thracians and Iberians all traced descent through women. In view of these facts it is useless to urge that because the Picts of Scotland and the ancient Irish had that system of succession through females these peoples must have been non-Aryan.

We have now reviewed the three main criteria of race at present used by anthropologists: (*a*) pigmentation of the skin, hair, and eyes; (*b*) the shape of the skull and other osteological characteristics; and finally (*c*) their system of tracing descent. We have seen that osteological differences may be but foundations of sand, because it is certain that such variations take place within very short periods, not only in the case of the lower animals, as in the horse family, but in man himself. Pigmentation is no true criterion, for we have found a steady tendency to change in colour in the case of the lower animals from latitude to latitude, whilst in the case of man the steady shading off in colour from dark to blonde may be traced from the equator to the Baltic. Unless then we postulate that man is entirely free from the natural laws which condition the osteology and pigmentation of other animals, we must admit that neither bone nor colour differences can be regarded as crucial criteria. Further, we saw that the test of descent through males or females broke down absolutely in the case of peoples who can be proved historically never to have spoken any but a non-Aryan language. Finally, we are forced to the conclusion that language, now that we realise what are the laws which govern its borrowing by one race from another, is really the surest of all the known tests of race when dealt with broadly and over wide areas, and not merely in the way of guesswork etymologies.

II. Hitherto I have dealt only with the need of a rigid application of zoological laws in studying the evolution of the various races of man. In the time that is still left I propose to touch briefly on the vast importance of such natural laws when dealing with the native races of our great dependencies and colonies, and in our own social legislation. I venture to think that the gravest mistakes which at present are being made in our administration and legislation are due to the total disregard of the natural laws, which not only modify and differentiate one race from another, but also are constantly producing variations within our own community. As physical characteristics are in the main the result of environment, social institutions and religious ideas are no less the product of that environment. Several of our most distinguished Indian and Colonial administrators have pointed out that most of the mistakes made by British officials are due to their ignorance of the habits and customs of the natives. It has been in the past an axiom of British politicians that in the English Constitution and in English law there is a panacea for every political and social difficulty in any race under the sun. Only let us give, it is urged, this or that State a representative parliamentary system and trial by jury and all will go well. The fundamental error in this doctrine is the assumption that a political and legal system evolved during many centuries amongst a people of North-Western Europe, largely Teutonic, and that too living not on the mainland but on an island, can be applied cut and dried to a people evolved during countless generations in tropical or subtropical regions, with social institutions and religious ideas widely different from those of even South Europeans, and still more so from those of Northern Europe. We might just as well ask the Ethiopian to change his skin as to change radically his social and religious ideas. It has been shown by experience that Christianity can make but little headway amongst many peoples in Africa or Asia, where on the other hand Muhammadanism has made and is steadily making progress, acting distinctly for good, as in Africa, by putting down human sacrifice and replacing fetish worship by a lofty monotheism. This is probably due to the fact that Muhammadanism is a religion evolved amongst a Semitic people who live in latitudes bordering on the aboriginal races of Africa and Asia, and that it is far more akin in its social ideas to those of the Negro or Malay than are those of Christianity, more especially of that form of Christianity evolved during the last twelve centuries by the Teutonic peoples of Upper Europe, who are of all races furthest in physical characteristics, in religious ideals and social institutions, from the dark races of Africa and Asia. This great gulf is due not merely to shallow prejudice against other people's notions, it is as deep-seated as is the physical antipathy felt by the Teuton for the Negro, which is itself due to the very different climatic conditions under which both races have been evolved. The Teuton does not freely blend with the black, and even when he does intermarry he treats his own half-bred progeny with contempt, or at most with toleration. On the other hand, some South Europeans, for example the Portuguese, are said to have little objection to intermarrying with dark races and allowing the mixed progeny an equal social status, whilst the Arab through the ages has freely taken to wife the African, and has never hesitated to treat the hybrid offspring as equals. There is thus a wide breach between the physique and the social and religious ideas of the African and our own; but, as political and legal institutions are indissolubly bound up with social and religious, it follows inevitably that the political and legal institutions of a race cradled in Northern Europe are exceedingly ill adapted for the children of the equator. Accordingly in any wise administration of these regions it must be a primary object to study the native institutions, to modify and elevate them whenever it may be possible, but never to seek to eradicate and supplant them. Any attempt to do so will be but vain, for these institutions are as much part of the land as are its climate, its soil, its fauna, and its flora. 'Naturam expellas furca, tamen usque recurret.' Let us hope for a successful issue for the effort now being made by the Royal Anthropological Institute to establish an Imperial Bureau of Anthropology whose function will be not only to carry out systematically the scientific study of man, but also to aid the administrator and the legislator, the merchant and the missionary.

III. I now pass to my last and most important topic—natural laws in relation to our own social legislation. We have seen that environment is a powerful factor in the differentiation of the various races of man, alike in physique, institutions, and religion. It is probable that the food-supply at hand in each region may be an important element in these variations, whilst the nature of the food and drink preferred there may itself be due in no small degree to climatic conditions. Each zone has its own peculiar products, and beyond doubt the natives of each region differ in their tastes for food and drink. The aboriginal of the tropics is distinctly a vegetarian, whilst the Eskimo within the arctic circle is practically wholly carnivorous. In each case the taste is almost certainly due to the necessities of their environment, for the man in the arctic regions could not survive without an abundance of animal fat. It is probable that the more northward man advanced the more carnivorous he became in order to support the rigours of the northern climate. The same holds equally true in the case of drink. Temperance reformers would enforce by legislation complete abstinence from all alcoholic liquors, and they point to the sobriety of the Spaniards, Italians, and other South Europeans, and urge, if these nations are so temperate, why should Britons and Irish continue to drink beer and spirits in such large quantities? This appeal depends unfortunately on the false assumption that the natives of these islands enjoy the same climate as the people of the sunny south. All across Northern Europe and Asia there is a universal love of strong drink, which is not the mere outcome of vicious desires, but of climatic law. In Shakespeare's time 'your Englishman was most potent in potting,' and this was no new outbreak of depravity, for the earliest reference in history to the natives of these islands tells us the same tale. When Pytheas of Marseilles travelled in these regions, about 350 B.C., he found the people making 'wine from barley,' and, though he does not explicitly say so, we need not doubt that it was meant for home consumption. In view of these facts we must regard this tendency as essentially climatic. This view derives additional support from the well-authenticated fact that one of the chief characteristics of the descendants of British settlers in Australia is their strong teetotalism. This cannot be set down to their having a higher moral standard than their ancestors, but rather, as in the case of Spaniards and Italians, to the circumstance that they live in a country much warmer and drier than the British Isles. We must therefore, no matter how reluctantly, come to the conclusion that no attempt to eradicate this tendency to alcohol in these latitudes can be successful, for the most that can be done by the philanthropist and the legislator is to modify and control it, but especially by moral means.

I have spoken of the principles at work in the differentiation of one race from another. It may be that the same principles or others closely allied may be at work within each community, for each community is but the whole world writ small. Within the United Kingdom itself there are not only different physical types, but very different ideas respecting marriage and divorce embodied in the laws regulating those fundamental institutions in England, Scotland, and Ireland. If such fundamental differences exist in that most important of social institutions, we may well expect that the natural laws which differentiate one race from another may be at work within every community in the United Kingdom.

Yet though the world has been ringing with the doctrine of natural selection and the survival of the fittest for nearly half a century, no statesman ever dreams of taking these great principles into consideration when devising any scheme of education or social reform. On the contrary, it is a fundamental assumption in all our educational and social reforms that all men are born with equal capacities; that there is no difference in this respect between the average child of the labourer, sprung from many generations of labourers, and one born of many generations of middle or upper-class progenitors; and it is held that all that is necessary to make the children of the working classes equal, if not superior, to the children of the bourgeois is the same food, the same clothing, and the same educational advantages. On that account we have devised the so-called educational ladder. Yet if we ask any social reformer why are there middle classes, the answer will probably be that they are better off. But why are they better off? We are told that their fathers and mothers were better off, and that they thus got a better chance than the poor labourer. But why were the parents of these middle-class folks better off? Oh! they came of families that had been long well-to-do. But why were these families long well-to-do? At last we are brought to the conclusion of the northern farmer, that 'Work mun 'a gone to the gittin' whiniver munny was got,' and to his brutal correlative respecting the labourers that 'Them or thir feythers, tha sees, mun 'a beän a laäzy lot.'

Work no doubt has been a main factor in the evolution of the middle and upper classes, especially in later times, though undoubtedly other qualities, such as superior physique and superior courage, have been very important elements in the earlier stages. But at all times it is not improbable that the special quality which led to their rise was a superior self-restraint, that enabled them to resist the vices which are too often attendant on prosperity. This superior morale acts in turn upon the offspring by setting up a better standard of life in the home, which of itself gives children brought up in such an environment an advantage at the outset of life denied to the children of inferior parents. It needs no elaborate induction to prove that the middle classes are not the outcome of chance, but of a long process of natural selection and the survival of the fittest in the struggle for life, the two main factors in this evolution being, in the language of Aristotle, heredity and training. Each community is but a microcosm of the whole human race, which, as I have endeavoured to show, is bound by the same laws as the rest of the animal kingdom. One race becomes a master because of its superior physique, courage, brain power, and morale; another sinks in the struggle or lags behind owing to its inferiority in the very qualities which have given the mastery to its rival. What is true of master races in relation to inferior races is equally true of the individuals in each community. The middle and upper classes are in the main sprung from ancestors with better physique, courage, and morale, and who have generation after generation been brought up in a better moral atmosphere than the children of the masses. Their ranks are also continually being reinforced by the best of the working classes. But this is not due to any educational ladder provided in modern times, for the process has always been at work, though of course its action has been distinctly aided by modern legislation. Mediæval history supplies many examples of those who, though sprung from the humblest parents, rose to high place in Church and State. This was not due to any legislative enactments, but rather to a principle well known in the whole field of Nature. Everyone knows that the superior varieties of flowers and vegetables are commonly the 'sports,' as they are termed, from inferior species. The skilful gardener watches carefully for good 'sports,' for they may become very valuable additions to his *répertoire* of useful plants. So, too, the legislator must watch carefully for good human 'sports,' not for those with criminal propensities. In the mediæval world the Church provided a ladder by which the son of the peasant could rise to be the counsellor of kings and princes. In modern times the State provides an educational ladder by which the child of the humblest parents may rise, if it has the capacity, to the highest positions in the community. It is right—nay, essential—that such a ladder should be provided, but this ladder is not for the mass of children. The vast majority can never climb beyond its lowest rung owing to their heredity, and in a less degree to their home environment. The ladder is for the good 'sports,' who by its aid are thus continually reinforcing with fresh blood the ranks of the middle and upper classes.

It may be said that I underrate the number of the good 'sports.' Of course it is very difficult to get any exact statistics on so complex a subject; but according to information which I have obtained from one of our great industrial centres, where the educational ladder enables any child who passes the fourth standard in the primary schools before it is eleven to rise into the secondary schools, it is probable that no more than 5 or 6 per cent. of the children of the working classes have at the age of sixteen the same amount of brain power as the average children of the middle classes at the same age. But even all this 5 or 6 per cent. of 'sports' cannot be credited to parents of the working class alone, for it may be that a certain proportion of them must be ascribed to middle or upper class parents. Of course these rude statistics must be corrected by others collected on a large scale all over the country before we can form a final judgment; but I believe that the evidence already to hand makes it improbable that more than a very limited percentage of the children of the working classes have the same ability as the average child of the middle classes.

In ancient days the chief end of the legislator was to produce a stalwart brood of citizens capable of bearing arms in defence of their country and advancing her material prosperity. Still more ought this to be the aim of our legislators to-day, for under modern conditions great masses of population are huddled together in a manner hardly known to ancient cities. To accomplish this great end, the legislator must not merely look to improved housing of the poor and the development of the physique of city populations. He must, as far as possible, conform to the principles of the stockbreeder, whose object is to rear the finest horses, cattle, or sheep. Amongst wild animals Nature selects the fittest for continuing the race, and the wise breeder simply aids Nature by selecting still more carefully the best animals. The legislator, on his part, ought similarly to foster the increase of the best element in the State, and on the other hand discourage the multiplication of the worst. Yet in our community statesmen of both parties have adopted the very opposite policy. The children of the working classes are educated at the cost of the State, the offspring of the wastrels are given free meals, and already there are demands that they shall be clothed at the expense of the ratepayers, and that the parents shall even be paid for providing them with lodging. It is not impossible that before long these demands will be conceded by either party in the State. The heavy additional expense incurred in this policy falls upon the middle-class ratepayers and taxpayers, who have to feed, educate, and clothe their own children at their own expense. It may be said that they can get free education for their children by sending them to the State schools; but this is to level down instead of to level up; for if they do so, they will be lowering the general morale of their own class, the most priceless asset of the nation. The heavy burden of taxation entailed by this policy, falling as it does with special weight on the middle classes, renders it more difficult each year for the young men and the young women in that class to marry before thirty, for they naturally shrink from the expense of bringing up large or even moderate-sized families. We need not then wonder at the falling-off in the rate of increase of the middle classes. Our legislators are bad stockmasters, for they are selecting to continue the race the most unfit physically and morally, whilst they discourage more and more the increase of what we have proved to be the outcome of a long process of natural selection. The present policy therefore tends to reduce that which in all ages has been the mainstay of every State, the middle class. The yeomen of England, the free burghers of Germany and of Italy, formed the best element in the Middle Ages. So was it also with the great republics of the ancient world. Aristotle, in more than one passage, has pointed out that the middle class, that which stands between the 'excessively wealthy' and the 'very poor,' between the 'millionaire' and the 'wastrel,' are the mainstay of every State, and he shows that, where the middle class has been crushed out by the millionaire or the mob, ruin has inevitably overtaken the State. Indeed, it is clear that the chief defect in the Greek democracies was the smallness and weakness of the middle class, whilst it is notorious that Rome prospered only as long as the middle-class citizens flourished. Her downfall came when they were extinguished by the great capitalists, who made common cause with the masses against them. The latter had no patriotism, were incapable of bearing arms, and had no aspirations beyond free meals and popular entertainments at the expense of the State.

It is of great scientific interest to discover how the short-skulled peoples of Asia and Europe became differentiated from their long-skulled congeners; it is of great practical importance to apply to the administration of our great dependencies and colonies the lessons taught by anthropology; but it is infinitely more important to maintain a vigorous stock of citizens for the kingdom and the empire. Questions of the origin of races are, after all, only academic; but the other two, more especially the last, are intimately bound up with the life of the nation. If the present policy of our legislators is adherred to, the moral and the physical standard of the British citizen will steadily deteriorate, for the population will gradually come to consist of the posterity of those who are themselves sprung from many generations of the most unfit. Should this unfortunately come to pass, it will be the result of human pride refusing to apply to the human race the laws which inexorably regulate all Nature.

The following Papers were read :—

1. *The History of Mummification in Egypt.* *By* Professor G. Elliot Smith, *M.A.*, *M.D.*, *F.R.S.*

In predynastic times in Egypt it was the custom to bury the bodies of the dead in the sand, roughly wrapped in skins, linen, or matting. As the result of the dryness of the soil, and the exclusion of the air by the close adaptation of the sand to the body, desiccation often occurred before any putrefactive changes set in, and the corpse thus became preserved in a permanent form.

This phenomenon must have been perfectly familiar to the prehistoric Egyptians themselves, for we have abundant evidence of the fact that plundering of graves was common even at this early period. Moreover, the people of later times must have learnt for themselves how excellently Nature preserved the corpses of their predecessors, when they came to make tombs for themselves in long-forgotten predynastic graveyards.

Thus the idea must have naturally presented itself to the Egyptian people, perhaps in early dynastic times, to attempt to secure by art the preservation of their dead, which was no longer attained naturally, once it became the custom to put the body into a coffin or a rock-cut chamber, because the air thus buried with the corpse favoured putrefaction. The Egyptians would be encouraged in these attempts, to which they no doubt were prompted by their religious beliefs no less than by the natural inclination of all mankind to preserve the remains of those dear to them, by the help which the properties of their soil and climate afforded them, as well as by their knowledge of the properties of the preservative salts, found ready at hand in such abundance in Egypt, and of the resins obtained from neighbouring lands, with the properties of which they had been familiar even in predynastic times. In this way the origin of the idea, the reason for attempting to put it into practice, and the means for doing so become intelligible to us, and render it more than ever improbable that the custom of embalming could have been imported into Egypt from some foreign land, where none of these reasons for the initiation of the practice holds good. We have no exact data to permit us to say exactly when embalming was first attempted in Egypt. Although the earliest bodies certainly known to have been embalmed are of the period of the tenth dynasty (found at Sakkara by Mr. Quibell), there is some slight evidence to suggest that some form of mummification was attempted in the times of the earliest pyramid-builders.

By the time of the Middle Empire the general technique of the operation had attained the stage which in its main features was the conventional procedure for the succeeding two thousand years. But it was in the time of the New Empire that the process of mummification reached its highest development. Then for the first time the embalmers learnt how to remove the brain and pack the cranium, and put into practice the elaborate and difficult measures for restoring to the dead body a greater semblance to the form it had had in life; so that the statue of the deceased, which had been an essential part of the furniture of the tomb in earlier times, when the body either underwent corruption or was imperfectly preserved, became superfluous, and was no longer put into the tomb.

Further stages in the evolution of the art of embalming were followed by a rapid decline.

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2. *A Sequence of Egyptian Stone Implements.* *By* C. T. CURRELLY.

The rough early pieces are found in the cemented quaternary gravels of the Thebaid. The regular palæolithic forms are found lying exposed on the rocks of the upper plateau and on the side-hills bordering the Nile valley. The development of the palæolith may be seen from the depth of the patina and also the scratchings; fourteen distinct shades of colour may be seen.

The flint of the Thebaid is of a uniform kind and colour, and except for the oldest forms the implements have been lying on the plateau under the same conditions for different periods of time. In addition to the depth of colour many pieces are reworked and show more than one patination. Several thousand pieces were examined, and form and patination were found to go together. Each type of implement has definite limits of patination, *e.g.*:—

Old points	1–3
Round butted lanceolate	2–4
Sharp " "	3
Round " " ovates	3–6
Sharp " " "	3–5
Thick ovates	3–5
Flat "	3–7
(So-called *coup de poing.*)	
Moustier point	7
Thick discs	2–14
Flat "	2–10
Lance-points	4–12
Hollow scrapers	4–12
(Majority 9–12.)	
Triangular implements	4–14

The neolithic implements of the Thebaid show little patination; a few are found on the top desert and these show a slight patination. The Fayoum neoliths show a considerable amount of patination and also reworking. In these the patination is different from those of the Thebaid, as the flint is of a different kind.

The enormous duration of the neolithic period is shown by the number of totally unpatinated implements that are made by reworking deeply patinated neoliths. The forms similar to those obtained from the predynastic tombs show little or no patination.

The catalogue of the collection in the Cairo Museum (with about sixty plates of illustrations) will be published shortly, and the question of patination and development will be dealt with.

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3. *The Veddas.* *By* C. G. SELIGMANN, *M.D.*

The Veddas may most conveniently be considered under three headings, Veddas, Village Veddas, and Coast Veddas, for it seems that at the present day the Veddas fall into three groups characterised by different sociological features. The coast Veddas fish and have borrowed largely from their Tamil neighbours, while the village Veddas have, to a considerable extent, intermarried with the Sinhalese. But in spite of these lapses both groups retain the remains of their old clan organisation in the majority of their settlements, showing their connection with those less contaminated and wilder folk who have commonly been spoken of as 'rock' or 'jungle' Veddas. On the psychical side, the life of all Veddas is unusually limited in every aspect except one, namely, their regard for the dead, and even this regard, which attains the intensity of a cult, has given rise to no decorative art; indeed a number of crude drawings, for the most part of animals and men, executed on the walls of certain caves, were the only examples of decorative art seen, and personal adornment is at the lowest ebb. But although this cult has produced no pictorial or plastic art, it has given rise to a series of dances, often pantomimic, and so, perhaps, in the nature of imitative magic, but whether pantomimic or not, accompanied, except in certain exceptional circumstances, by offerings of food to the spirits of the departed. Though others take part in them, these dances are performed especially by men who have been trained to invoke the *yaku*, as the spirits of the dead are called, and the use of a ceremonial arrow with a blade over a foot long and a short handle is an indispensable feature of some of these ceremonies, in all of which the 'shaman' becomes possessed by one or more of the *yaku* he invokes.

Finally as to language: all Veddas speak Sinhalese or dialect of Sinhalese with a predominance of *ch* sounds which makes Vedda talk sound harsh, and has led to the belief that they have a language of their own; but in addition many Veddas have also a small number of words which are not obviously Sinhalese, or are Sinhalese periphrases; these classes of words are specially used in hunting and in addressing the *yaku*.

FRIDAY, SEPTEMBER 4.

The following Papers were read:—

1. *Anthropological Work in Egypt.* *By* Professor G. Elliot Smith, *M.A.*, *M.D.*, *F.R.S.*

The earliest known human remains found in the Nile Valley, when compared with those of later times, demonstrate the fact that in predynastic times Egypt and Nubia were inhabited by one and the same race, which has persisted in Egypt with little or no change in physical characteristics throughout the intervening six thousand years until the present day. They were and are a small people, the average height of the men being about 5 feet 3 inches at every period of their history; their hair is very dark brown or black, usually wavy, but not 'woolly' or in any sense negroid; their heads are long and narrow, usually ovoid or pentagonoid or 'coffin-shaped,' as the result of a frequent presence of a protuberant occiput. On the whole they share those characteristics which distinguish the majority of the peoples fringing the Mediterranean—the populations of Sicily, Italy, Southern France, Spain, Algeria, and Tunis.

The physical characters of the population are remarkably uniform; they exhibit a range of variation, which is not appreciably greater than that of the purest races known to us, though, of course, it is easy to select the extremes of these variations and call them 'coarse' and 'fine' types or 'negroid' and 'non-negroid' strains.

As we should expect in a group of people that has lived from the dawn of history on the fringe of the negro territory, there is some slight evidence of an infusion of black blood, but this is very small in amount, and its effects very much slighter and less widely diffused than is commonly supposed to be the case. The negro influence is least marked, if indeed it is not a negligible factor, in the earliest predynastic times; but it becomes more and more pronounced in later, and especially so in modern, times.

From the time of the earliest Egyptian dynasties a noteworthy change occurs in the physical characteristics of the people of Nubia, and, though in a very much slighter degree, in Lower Egypt. The inroad of negroes from the South leads to the transformation of the Nubian population into a hybrid race. And there is some evidence to show that even at the time of the pyramid-builders there was some influx of an alien race from the Levant, which intermingled with the predominant Egyptian population of the Delta.

Three thousand years later a much greater immigration of people presenting the same alien characteristics poured into Egypt and Nubia. From this time onwards these foreign immigrants came to Egypt in a constant stream; and as they intermarried with their co-religionists—the Christian Copts—it happens that a considerable proportion of the latter present less resemblance to the ancient Egyptians than their Moslem neighbours, who have intermarried either with their fellow-countrymen or with the less dissimilar Arabian or Berber peoples of the same faith as themselves.

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2. *Rajputs and Mahrattas.* *By* W. Crooke, *B.A.*

This paper was mainly devoted to a consideration of the views recently enunciated by Sir H. Risley on the origin of the Rajputs and Mahrattas.

The former are classed by him, on the evidence of anthropometry, as 'Indo-Aryans.' But historical and other evidence points to the conclusion that, so far from being a distinct ethnical unit, the Rajputs form a *status* group, compounded from varied elements. Thus, in the Ganges valley and along the central ranges of hills many Rajputs are promoted from the indigenous, so-called 'Dravidian,' races. This fact is familiar to all ethnologists. More important and novel is the evidence from epigraphy recently discovered, which shows that many of the Rajputs in the Punjab and Rajputana are sprung from Scythian and Hun invaders. These foreigners were a brachycephalic people; and the failure of craniometry to detect this strain in the present population may be due either to insufficient investigation, or to the impossibility of classifying mixed races on the basis of skull form.

Next, it was shown that there is no historical justification for the assumed Scythian entry into the Deccan and Southern India as far down as Coorg. The presence in those regions of a brachycephalic strain, whatever may be its origin, cannot be due to a Scythian or Hun invasion.

The Mahrattas, again, do not constitute a stable ethnical unit. They are a *status* group, the basis being the 'Dravidian' or indigenous Kunbi tribe. The higher classes, owing to their rise in social importance, have asserted and obtained the right of *connubium* with the Rajputs.

It was suggested that the influence of environment and sexual selection have been to some extent overlooked in recent discussions on the ethnology of India; and that these causes may possibly explain the uniformity which characterises the physical character of the people of the Punjab.

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3. *On a Collection of Dinka Laws and Customs.*[1] *By* E. Sidney Hartland.

The Dinkas are one of the most important tribes of the Egyptian Sudan. Captain Hugh D. E. O'Sullivan, a Government official, has recently compiled for administrative purposes a collection of their laws and customs. This collection is at present unprinted, and contains valuable anthropological material. The Dinkas are a pastoral people, the economic basis of their society being the possession of cattle. Their government is patriarchal, and they reckon descent only in the male line. Reasons were given for thinking that this exclusively male descent was preceded by exclusively female descent. Some curious details of custom were discussed; among others, the legal fiction (believed to be unique) by which an heir is provided when the male line has died out.

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4. *Four Weeks in New Britain.* *By* Miss B. Pullen-Burry.

Among the inhabitants of New Britain, two races stand out from the rest as possessing isolated features. The Sultkas of the south coast, known as *Spitzköpfe* from the artificial protuberance of the occiput, and the Bainings, only discovered ten years ago, now considered to be the aboriginals of the island.

[1] To be published in *J. R. Anthropological Institute.*

These latter are singular in that they are nomadic, have no totems, barter, not using the universally prevailing shell-money, and in their dances the sexes dance together. They believe in the invisible presence of spirits, but apparently have no dread of their return in any form, such as prevails everywhere else in the archipelago. The bush Kanakas' settlements, some fourteen miles from Herbertslöhe, were described, also the snares used for catching flying foxes, the sacred sign of three crotons, planted equidistant, in front of the chief's hut, in a separate enclosure, and the bachelors' hut in which dried bats are suspended from the roof to present to the brides.

5. *The Northern Mound-builders of North America.* *By* GEORGE BRYCE, *D.D., LL.D., F.R.S.C.*

The Northern Mound-builders described are, so far as known, the most northerly in North America. The sites examined were:—

1. The Red River, on whose banks, at the junction of the river with the Assiniboine River, the city of Winnipeg, Manitoba, stands.
2. The Rainy River (150 miles east of Winnipeg), which falls into the Lake of the Woods.
3. The Lower Souris or Mouse River, at a point some 200 miles south-west of Winnipeg.

Number of mounds seen:	1. Red River . .	9
	2. Rainy River . .	21
	3. Souris River . .	21
	Total . . .	51

Souris region: (*a*) The Roches Percées. A remarkable group of sandstone rocks of the Tertiary period, standing on the open prairie, covered with Indian pictures of the elk, buffalo, Indian star, and teepee.
(*b*) Hill of the Murdered Scout.
(*c*) Near by the Red Pipestone Quarry of Longfellow.
(*d*) Remarkable earthworks on the south side of the South Antler, a tributary of the Souris.

The largest mound opened (on the Rainy River) was 110 feet long, 90 feet wide, and 30 or 40 feet high.

The following objects were obtained from the mounds:—

1. Birch bark skull.
2. Bones of birds (whistle, scraper, beads), present ornaments of bone.
3. Stone implements—hammer, conjurer's tubes, chisels, scraper, chucky stones.
4. Red and yellow ochre, lump of arsenical pyrites.
5. Copper—copper frontlets from skull, needle, cutting-knife, hook, arrow-head.
6. Pottery—cup, fragments of many pieces of pottery with different designs.

The purposes of the mounds appear to be two—1. Sepulture. 2. Observation.

The builders were not of the same race as the modern Indians. This is proved by Indian tradition, by their being agriculturists, metal-workers, and pottery-makers.

It is suggested that they were of Toltec origin, having been driven from Mexico up the Mississippi, then up the Missouri to the Souris, and then up the Ohio; others coming from the upper waters of the Mississippi to the Red and Rainy Rivers.

They seem to have been followed by the Sioux (Dakotas), Iroquois, who are probably of Aztec origin. About the time of the coming of the white man in the end of the sixteenth century they were, as Eries, Neutrals, and other pottery and metal workers, blotted out, leaving their mounds behind them.

6. *Prehistoric Archæology in Japan.* *By* N. GORDON MUNRO.

During the past quarter of a century the observations of Japanese and foreign investigators have enabled some general conclusions to be made. Features not shared by other cultures have been isolated, while the resemblance of culture vestiges to those of other lands agrees with the general verdict of prehistoric intercommunication. Here also the great number of crude stone implements and the persistence of horn and bone harpoons of palæolithic form suggest a direct survival from the earlier culture, while some indications of an evolution are present. But no remains of undeniably palæolithic status have been found. Stones have been recovered from the drift gravel of the Sakawa Valley, but their human manufacture is not positively determined. Excavations of shell-mounds and other neolithic sites in Japan have revealed some connection between the pottery of this phase and that of the iron culture which accompanied the agricultural invaders from the mainland of Asia. These formed the core of the present Japanese nation. The neolithic inhabitants were gradually driven to the east and north, but miscegenation took place to a greater extent than is generally supposed.

The present school of Japanese archæology, led by Professor Tsuboi, is mostly in favour of the view that the primitive inhabitants of Japan were not of the same stock as the surviving Ainu. The opposite thesis has been maintained by Professor Koganei, Messrs. Sato, Takabatake, and others. The discovery of Ainu remains in the shell-heaps and underlying soil proves that this people played a part in the neolithic culture.

The characters of the dolmens and other vestiges of the Iron phase, and the incidence of the former with the neolithic sites, favour the view that the progress of the invaders towards the east and north was slow, and might have commenced about five centuries B.C., or even earlier. Observations on the orientation of dolmens have been made, but exact work of this kind is slow, on account of the necessity of correcting the compass declination by star observations. Sufficient material has not been accumulated to place it beyond question that alignments were made to the rising or setting sun or to stars.

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7. *Some Ancient Stone Implement Sites in South Africa—their bearing on the Problem of the Antiquity of Man.* *By* Rev. W. A. ADAMS, *B.A.*

The sites examined were five in number:—

1. The hill-slope near the coast at Bosman's Crossing, Stellenbosch, yielding rudely chipped picks and other implements of the palæolithic type, embedded in clay.

2. The Karoo, near Kimberley. From this were collected weather-worn specimens, chiefly, showing the transition from the older form of palæolithic implement to the neolithic axe.

3. The Vaal River terraces, near Kimberley. Here is an extensive stone implement site at Pniel, where the process of manufacture, from the block of stone to the finished implement, can be clearly traced.

Higher up the banks 'pygmy' implements were also discovered.

4. The uplands of Rhodesia, near Bulawayo. Roughly chipped disc-like scrapers were procured, and well-made 'pygmies.'

5. The headlands at the Victoria Falls. Palæolithic implements were here collected, some of them of chalcedony, of large size and highly glazed. A few flakes are water-worn. Was ancient man on the headlands here when the river was flowing along the high levels?

MONDAY, SEPTEMBER 7.

The following Reports and Papers were read :—

1. *Report on Excavations on Roman Sites in Britain.*

See Reports, p. 342.

2. *Recent Excavations at Roman Chester.* *By* Dr. R. NEWSTEAD.

During the demolition of some house property in Chester a section of the Roman Wall was discovered, of a total length of 56 feet 10 inches. It is built of ashlar, the greatest height of this wall being approximately 6 feet 6 inches, and consisting of seven courses of masonry laid in very regular and for the most part closely jointed courses without mortar joints or embedding. The ashlar work is backed by rubble of roughly hewed pieces of rock coursed more or less to correspond with the masonry. Large quantities of soil were used to fill in the cavities between the masonry and rubble. The foundations were deep and built of rubble similar to the inner lining. The lowest course was formed of a single layer of boulder stones buried in mortar and resting on a stratum of soft undisturbed red sandstone. Behind the rubble of the wall was found a solid bank of stiff clayey loam 5 feet in height. It is probable that this wall of clay was at one time supported by masonry or stonework. The house was excavated in two places and a portion exposed in a third. It was not of the usual V-shape, the bottom being broad and flat and measuring 4 feet 4 inches in width. The greatest width from lip to lip was approximately 22 feet, and the greatest depth 9 feet 3 inches.

Among the finds were shells of *helix aspersa*, bones of frog, and portions of the pelvis of a sheep or goat. Fragments of amphoræ and cinerary urns of Upchurch ware, pieces of Samian, roofing tiles and imbrices, pieces of glass, one of an amber-green colour hitherto unrepresented at Chester, a bone pin and two coins, one probably a first bronze of Hadrian, were also discovered. The only prehistoric implement found was a beautifully preserved flint axe of palæolithic type.

3. *Some Remarks on the Irish Horse and its Early History.* *By* Dr. R. F. SCHARFF.

That the modern Connemara pony possesses certain features of resemblance to Arab horses is well known, and has been recently emphasised by Professor Ewart in his description of the various Irish breeds of ponies. This character is currently believed to be due to a comparatively recent introduction into Ireland of Eastern stock. Professor Ridgeway not only puts the date of this introduction as far back as pre-Christian times, but he contends that these supposed Eastern horses were imported from France, and were originally of Libyan origin.

The most complete remains of the ancient horse discovered in Ireland were obtained by Mr. George Coffey in the Craigywarren Crannog, county Antrim. The human implements and weapons found with them imply that the occupation of the Crannog dates back to early Christian times. The horses were then, no doubt, domesticated. Their resemblance to the Arab type of horse is quite as striking a feature as that in the modern Connemara pony.

The remains from a tumulus and from Irish bogs, marls, and caves in the Irish National Museum are less complete, but they all indicate that in still more remote times a small race of horse, apparently similar to that of the Crannog period, lived in Ireland. It is important to note that some of these remains probably belonged to wild races.

The available evidence seems, therefore, to support the view that the resemblance of the modern Connemara pony to the Eastern or Libyan race of horse is not entirely due to human introduction of foreign stock, but to the fact that the wild horse of Ireland possessed the same characteristics as the latter and transmitted them to the existing ancient domestic breeds.

4. *The Distribution of Gold* Lunulæ. *By* George Coffey, *M.A.*

Of the known examples of this most characteristic of Irish gold ornaments sixty have been discovered in Ireland itself, six in France, four in England, four in Scotland, two in Denmark, and one each in Wales and Belgium. They may be dated provisionally between 1200 and 1500 B.C.

That they are essentially an Irish ornament is clear from their distribution, and the finding of examples in other parts of Western Europe may point to early raids from those districts or to an early trade for gold with the Irish people.

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5. *A Leather Shield found in Co. Longford.* *By* E. C. R. Armstrong.

The shield, which is of circular form, was found in June 1908 in a peat bog. It is made of a solid piece of leather, and is $20\frac{1}{2}$ inches in length and $19\frac{1}{2}$ inches across. It has an oblong central boss, which has been pressed out of the leather and furnished with a cap, of finer leather, laced into the boss. The face of the shield is ornamented with three ribs, between which are small bosses, arranged in sets of three, recalling the decoration of bronze shields. The back of the shield is furnished with a leather handle. That the specimen is not the leather lining of a bronze shield is clear from the thickness of the leather and the lacing of the boss. It is of the same type as the bronze shields common in Upper and Western Europe.

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6. *The Survival of La Tène Ornament in some Celtic Penannular Brooches.* *By* George Coffey, *M.A.*

The date of these brooches can be safely claimed as not later than 700 A.D., from the complete absence of any trace of interlaced ornament in them, as well as from the many La Tène elements surviving in their decoration. Many of them are no doubt earlier, and may antedate the coming of St. Patrick. All are of bronze, but the enamels with which they were decorated have disappeared.

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7. *Note on the Tara Brooch.* *By* George Coffey, *M.A.*

The particular feature of the brooch with which the paper dealt, and which had not previously been noticed, was that the fine wires of the interlaced patterns, of the central interlacements, and of the head of the pin have a minute granulation, hardly apparent to the naked eye.

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8. *The Origin of Irish Motes.* *By* Goddard H. Orpen, *B.A.*

The scientific investigation of Irish earthworks is only in its infancy. This paper was concerned with classes D and E of the 'Scheme for recording Ancient Defensive Earthworks,' as recommended by the Congress of Archæological Societies.

Ireland offers some advantages over the sister island as a field for the study of motes:—

1. Existing motes are more numerous and less mutilated than in Britain.
2. From the known history of Ireland, the peoples to whom the erection of its motes can be ascribed are practically reduced to three, viz.:—

(*a*) The Celtic tribes, meaning thereby the race or races that exclusively occupied Ireland prior to the Scandinavian invasion of the ninth century.
(*b* The Scandinavian invaders themselves.
(*c*) The Normans, who first came to Ireland.

As to the hypothesis of a *Celtic* origin—(1) the local distribution of motes is impossible to explain on any theory which would ascribe them to Celtic tribes *generally*. (2) There is no mention in early Irish documents of an artificial mound as forming part of a Celtic fortress. (3) At the time of the coming of the Normans the Irish had few or no castles, and there is no account of the siege or assault of any Irish castle. Indeed it is not contended by the advocates of this hypothesis that motes were in use by the Irish when the Normans came, and the only current rival to the hypothesis of their Norman origin is one that would ascribe their erection to very early, and even prehistoric, times. The unscientific nature of the arguments put forward on behalf of 'the prehistoric theory' is easily demonstrable.

Thus in 1169 the Romans and the early Saxons, Angles, and Jutes are excluded. The hypothesis of a *Scandinavian* origin of Irish motes, though once widely held, is now discredited. Motes have not been observed in the countries from which the Northmen came, and are non-existent or rare in many parts of Ireland which appear to have been specially occupied and dominated by them, *e.g.*, the district near Armagh, the co. Clare, and West Munster.

As regards the remaining hypothesis, that motes were erected by the *Normans* at the close of the twelfth century and beginning of the thirteenth, the following are the principal facts and inferences which, in the writer's opinion, establish it:—

(1) The Normans are known to have adopted this type of fortress in Normandy in the eleventh century, and the large majority of the castles they built in England towards the close of that century have been shown to include a mote.

(2) When a century later the Normans came to Ireland the mote-fortress suited the conditions of their warfare.

(3) There is contemporary documentary evidence that the Normans did erect certain motes in Ireland.

(4) Upwards of 80 per cent. of the probable sites of the castles known to have been erected by the Normans in Ireland prior to the year 1216 include a mote.

(5) The distribution of the motes in Ireland, so far as it has been ascertained, is completely explicable on the hypothesis that they were raised by the Normans, and seems to be inexplicable on any other hypothesis. Of the motes of Ireland, as far as known—228 in number, 74 are within the Anglo-Norman lordship of Leinster, 63 within the lordship of Meath, and 40 within the lordship of Ulster. In lands retained by the Crown there are 20 motes. In parts of the modern counties of Tipperary, Limerick, and Kerry, occupied by Normans prior to 1215, there are 24 motes. While in all Irish Connaught there are only six earthworks which can be classified as motes, and in all Irish Ulster there is only one; and these seven outlying motes can with probability be connected with early Norman settlers.

(6) The vast majority of these motes have been shown to be situated at early manorial centres.

(7) In many cases the remains, or at least foundations, of stone towers and other defences exist, or can be shown to have formerly existed, on the summit of motes, or in the attached base-courts, and these seem to have been the work of the Normans or of their Anglo-Irish successors, and to have taken the place of the original wooden defences.

Certain classes of artificial mounds must be distinguished from motes, viz., (*a*) sepulchral mounds, (*b*) ceremonial mounds.

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9. *On certain Changes in the Lateral Wall of the Cranium due to Muscular Development.* *By* Professor J. Symington, *M.D., F.R.S.*

The following are the results of a series of observations upon the relation of the temporal muscle to the skull and brain from birth until adult life. It was found that the muscle was small at birth compared with the brain-case, and consequently the temporal ridge was low at this period of life, only just reaching on to the parietal bone. After birth the muscle grows more rapidly than the lateral area of the skull, and gradually extends upwards upon it, so that the temporal ridge reaches a much higher level than in the infant. This extension of the muscular attachment proceeds gradually, and is probably not completed until adult life.

An index was constructed by taking a vertical line from the upper border of the zygoma to a point opposite the level of the bregma as equal to 100, and observing the ratio of this to a line starting from the same point below, and proceeding in the same direction as far as the temporal ridge. At birth the index is about 34 and in the adult about 68, so that at birth the temporal muscle occupies approximately the lower third of this zygomo-bregmatic line and in the adult its lower two-thirds. The process is not completed at puberty, for in a girl thirteen years the index was 59·6, and in another fifteen years it was 62·2. The growth of the temporal muscle is associated with that of the jaws and teeth, and is independent of brain growth.

The parts of the brain situated in the mesial plane were projected outwards orthogonally on to the lateral aspect of the skull. Drawings prepared in this way showed that at birth the area occupied by the temporal muscle was distinctly below the whole of the corpus callosum, and did not reach backwards to the level of its posterior border; whereas in the adult the corpus callosum was entirely within the temporal region. A series of specimens, arranged according to age, between infancy and adult life exhibited a gradual expansion of the temporal area towards, upon, and finally above and behind the corpus callosum. During this period the height of the corpus callosum maintained a fairly constant relation to that of the cranium, and the rates of growth of these two structures closely corresponded with each other.

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10. *The Development and Adult Form of the Human Brain. By* Professor A. Fraser.

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11. *The Significance of the so-called Accessory Dental Masses sometimes found in the Upper Jawbones. By* Professor A. Francis Dixon.

An examination of a group of young Ibo skulls from West Africa leads to the belief that the small 'accessory dental masses,' which may occur in the maxilla between the second premolar and the first molar, have not the important morphological significance sometimes attributed to them. It has been suggested that these rudiments, which are fairly common in negro skulls, represent aborted or vestigial premolars corresponding to the third premolars of platyrrhine apes. The Ibo skulls examined do not bear out this interesting suggestion, for in them the rudiments can be seen to arise as unabsorbed portions of the second milk molar. In some of the specimens the actual method of their formation can be followed. The origin of the rudiments explains their rather variable microscopic structure and the absence, or relatively small amount, of enamel usually present. The question as to why fragments of the second milk molars should be relatively so frequently retained in certain races is one of considerable interest.

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12. *Who Built the British Stone Circles? By* J. Gray, *B.Sc.*

Closely associated with dolmens and avenues in Britain, there are three leading types of stone circles—namely, the Dartmoor, the Aberdeenshire, and the Inverness types, the simplest forms being found in the south.

The distribution of stone circles in Britain would be simply explained if we assume that the race who built them first settled in Cornwall and Devon, then migrated up through Wales, Lancashire, and South-West Scotland as far as the mouth of the Clyde, from thence across the midlands of Scotland to the mouth of the Tay, then north along the east coast, through East Aberdeenshire, turning west to Inverness, and after that north through Caithness to the Orkney Isles and Lewis.

A large number of the river names in this stone circle area are evidently derived from the same root as *Devon*, thus indicating one important tribal name among the stone circle race. The four rivers Dee (ancient *Deva*), for example, are found in this area.

The physical characters of the race with which the stone circles are associated are unique. It is demonstrable from available data that this race, which is assigned to the early Bronze Age, differs from all the other prehistoric races found in Britain; it also differs from the prehistoric races of Sweden, Denmark, and Switzerland. Since the physical type of North-West Africa excludes the probability of immigration from this region, we would appear to be driven to seek the original home of these people in some region of Asia which the present state of our knowledge does not enable us to identify with certainty. It is interesting to note here certain indications of affinity with the ancient people of South-West Asia.

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13. *Report on Anthropometric Investigation in the British Isles.* See Reports, p. 351.

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14. *Report on Archæological and Ethnographical Researches in Crete.* See Reports, p. 344.

TUESDAY, SEPTEMBER 8.

The following Papers and Report were read:—

1. *Excavations at Caerwent, Monmouthshire, on the Site of the Romano-British City of Venta Silurum, in* 1907–8. *By* T. Ashby, *M.A., D.Litt.*[1]

Of the excavations up to August 1907 an account was given at the Leicester meeting. The rest of the campaign of 1907 was devoted to the exploration of the Basilica and Forum, with the exception of the western portion of both, which lies beyond the limits of Lord Tredegar's property. It was possible to recover the plan of the whole block, which, surrounded by streets on all four sides, formed one of the twenty *insulæ* into which the town was divided, and it corresponds closely with that of the Forum of Silchester. An interesting feature is the large drain which carried the surface water off the open area under the Basilica and away to the north. The season of 1908 was devoted to the continuation of work in the *insula*, to the east of the Forum, to the south of a large house, numbered VII^{N}, excavated in 1906. Remains of a temple and of several private houses and some rubbish pits were found, one containing a peculiarly hideous seated statuette of a female deity.

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2. *The Work of the Liverpool Committee for Excavation and Research in Wales and the Marches. By* Professor John L. Myres, *M.A.*[2]

The Liverpool Committee for Excavation and Research in Wales and the Marches was constituted in October 1907, with the object of co-operating with existing agencies for the investigation of the early history of the Welsh people,

[1] To be published in full in *Archæologia*.

[2] To be published in full in the *Annual Report of the Liverpool Committee for Excavation and Research in Wales and the Marches.*

with special reference to the effects of the Roman occupation of Wales and of the non-Roman invasions which terminated and succeeded that occupation.

The Liverpool Committee has its headquarters in the Liverpool University Institute of Archæology, and carries on its work in close association with the School of Celtic Studies there. Its first task has been to enter into a close understanding with the local Archæological Societies, which have done so much for the archæology of Wales in the past; and in particular with the Cambrian Archæological Association, whose publications contain by far the most copious collection of materials for early Welsh history. Many of these societies are already engaged upon archæological surveys of their respective districts, and there is a general desire that as far as possible these surveys shall be carried out on uniform plan and scale.

The work of the Committee for the current year has been confined to the conduct of a preliminary survey of a few districts of Wales which have not yet been undertaken by any local society, and to tentative excavations on sites which seem likely to deserve more thorough examination in the near future. Such, for example, is the excavation of the Roman site at Caerleon, of which a summary is given below, by Mr. H. G. Evelyn-White. By these means the Committee expects to enter upon the work of the next season with an adequate staff of trained workers, and with a plan of investigation based upon a general survey of the present state of our knowledge of the country and its monuments.

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3. *Excavations at Caerleon, Monmouthshire.* *By* H. G. Evelyn-White.[1]

Excavations have recently been carried out at Caerleon on a piece of ground lately added to the churchyard. As 'quarrying' has been actively pursued on the site the plan could in some parts only be recovered by following mere foundations at a depth of 4 or 5 feet. The area excavated, judging by analogy, apparently is a little north of the site of the *principia prætorium.*

Among the finds were the lower part of a sandstone statuette, the base of which bore the inscription

'DEO MERCVRIO
[A]VR DD SEVER P (?),'

an amphora handle with the graffito (in cursive letters) 'AMINE,' and a few coins, chiefly of the Constantine family, but including one each of Carausius and Trajan.

The value of the excavations consists in the recovery of the ground plan, especially as this will shortly be inaccessible for ever.

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4. *Neolithic Culture in North Greece.* *By* J. P. Droop, *B.A.*[2]

Recent exploration of the neolithic culture of Northern Greece has shown that the plain districts of Southern Pelasgiotis, Thessaliotis, Phthiotis, Malis, and Phocis were inhabited from an early date by three peoples alike in culture, and near akin, but distinguishable by the varying style of their painted pottery. The mounds of accumulated deposit from their settlements are easily distinguishable in the plains.

The stone implements consist of celts (sometimes bored), rubbers, and polishers; while obsidian chips are much more frequent than flint.

One people lived in the district round Pagasæ and Pheræ; another in the plains round Pharsala and Itonos; and the third in Phocis, as far south as Chæronea. The two southern peoples show a nearer kinship.

[1] To be published in full in the *Annual Report of the Liverpool Committee for Excavation and Research in Wales and the Marches.*

[2] To be published in the *Annual of the British School of Archæology at Athens.*

The excavation of a mound called Zerelia in Phthiotis shows that the two northern peoples at least were contemporary, and that, as time passed, their art degenerated.

Traces of eight successive settlements show that the period of painted pottery gradually passed, after the fourth settlement, into a period of unpainted polished ware.

The eighth neolithic settlement is roughly dated to 1300 B.C. by the presence of imported Mycenean sherds.

A series of tombs sunk into the remains of this eighth settlement indicates a subsequent poor bronze period. Thus, during the development of the Ægæan bronze culture the north of Greece was still in an Age of Stone, and used bronze only at a comparatively late date, and presumably but for a short while before the introduction of iron.

The date at which these neolithic peoples brought in their comparatively high culture may be placed in the middle of the third millennium.

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5. *The Excavations of the British School at Athens at the Sanctuary of Artemis Orthia at Sparta.* *By* M. S. THOMPSON, *B.A.*[1]

The Sanctuary of Artemis Orthia, one of the most important centres of Spartan religion and especially celebrated for the annual scourging of the Spartan boys, was discovered in 1906, and this is therefore the third season of the work. In 1906 and 1907 a temple built in the middle of the sixth century B.C. was found, and in front of it a late Roman theatre, for the better witnessing of the rites, in the centre of which was the altar. The excavation of this arena and of the interior of the temple revealed a rough cobble pavement, and on it a large altar of undressed stones. The whole area was covered with a thick deposit of votive offerings of great importance, characterised by pottery ranging from geometric to orientalising. All these were clearly earlier than the temple, which may be dated to the middle of the sixth century, and contemporary with the large archaic altar mentioned above. The thickness of the stratum of votive offerings is such that its earliest date cannot be later than the middle of the ninth century, and as geometric sherds were found even lower than the pavement, the earliest occupation of the site may be about 900 B.C.

Thus at the end of 1907 both temple and altar had been found for the period from the middle of the sixth century onwards; this year's work gave the remains of the primitive temple contemporary with the great archaic altar, and like it resting on the cobble pavement. The mass of votive offerings was especially rich in its neighbourhood.

The primitive temple has been largely destroyed by the foundations of the later temple. The part preserved lies on the south side of the later building, and fairly symmetrically with regard to the altar, although the orientation is slightly different.

The remains were covered with a mass of earth burned red, recognisable as the remains of mud-brick walls destroyed by fire. Beneath this were the foundations of the end and part of the side of a rectangular building consisting of a single course of undressed stones. At the west end of this building the walls contained some vertical slabs *in situ*, and there were traces of a small inner cella. Along what was probably the central line of the building was a row of irregular stone slabs laid flat at intervals of about a yard, and corresponding to these in position were similar slabs set in the foundation of the walls. All the slabs seem to have supported wooden timbers, those built into the wall serving as a frame for the building, and the others forming a row of pillars down the centre. The eastern part was completely destroyed, and with it all possibility of recovering the form of the entrance. A fragment of roof-tile was found, but clearly later than the

[1] To be published in full in the *Annual of the British School of Archæology a Athens.*

building itself. This, however, almost certainly had a gable roof, with the row of pillars supporting the roof-tree. It is noticeable that the temple at Thermos in Ætolia, which replace a similar mud-brick building, had a row of pillars down the middle.

In this primitive building we may see the earliest Dorian style, and the conclusions drawn from its remains point to a building essentially identical with that which Doerpfeld has already reconstructed from the indications afforded by extant monuments of the developed Doric style.

Much progress has also been made in the excavation and study of the votive offerings. The suggestion that the so-called Cyrenaic pottery is really Laconian has been very fully confirmed by the discovery of Cyrenaic vases, and still more by the series of pottery leading up to and degenerating from the fine Cyrenaic style.

Of the terra-cotta masks which were such a feature of the excavation of 1906 many more have been found, and they have been proved to belong almost entirely to the late sixth and early fifth century, the period immediately following the building of the later temple. No ivory dates from this time, when its place was taken by bone. All the rich series of carved ivories, this year much increased, belong to the period when the primitive building was still standing.

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6. *Report on Archæological and Ethnological Investigations in Sardinia.* See Reports, p. 350.

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7. *The Sculptured Stones of Norway and their relation to some British Monuments. By* Dr. HAAKON SCHETELIG.

The sculptured stones of the Viking Age in Norway are not very numerous but are of great interest, as showing several different types. The standing stone of Kirkeide, in Nordfjord, is covered with symbols: the comb, the serpent, the group of four concentric circles, the crescent, and the radiated sun-disc, which are all found also in the early Christian monuments of Scotland. It is a proof of direct communication between Scotland and Western Norway about A.D. 700. Another stone in the same district bears a ship-figure only, and probably shows an influence from Gotland during the same period—viz., about A.D. 700. Such connections between Gotland, Western Norway, and Scotland have been suggested already by the late Professor Sophus Bugge, from some peculiarities in the form of the runes. Mr. Jacobsen has come to the same conclusion from Norwegian names of places in Shetland. Thus we see that direct communications between Britain and some parts of Scandinavia were opened at a time not a little earlier than the Viking expeditions recorded in history. A stone from Tu, in Jæderen, bears a runic inscription and simply carved representations of a man and a woman. By comparing them with a certain type of small gold leaves, impressed with figures, it is made out that they represent a mythical scene, probably personifications of the sun and the earth (Frey and Gerd). This monument must be assigned to the first part of the Viking Age, and, as its runes show the same peculiar character as the runes of the Norwegian crosses in the Isle of Man, its figures may also have been influenced by the sculptures of that island.

The sculptured stones of the early Christian time are chiefly found in the eastern parts of Norway; they are of a more ornamental character. Specially are mentioned the representations of Sigurd Favnesbane, a hunting scene, and the Three Kings.'

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8. *The Four Principal Aqueducts of the City of Rome in Classical Times. By* T. ASHBY, *M.A., D.Litt.*

Among the aqueducts which supplied the city of Rome the four which came from the upper valley of the Anio were the most important—the Anio Vetus, the Aqua Marcia, the Aqua Claudia, and the Anio Novus. Of these the first and the last, as their name implies, derived their water from the river itself, while the second and third were fed by springs which rose, and still rise, in the floor of the river valley.

Considerable remains of these conduits still exist, and well repay—what they have not of recent years received—careful study and examination. Their course, known fairly well as far as the village of Gallicano, in the district between the Sabine and the Alban Hills, has hitherto been treated as unknown between Gallicano and the point some seven miles out of Rome, where they emerge for the last time from the ground, and run upon arches into Rome. Careful investigation, and especially the search for pieces of the calcareous deposit brought down by the water, which was removed from the channels when they were cleaned (which must have been frequently necessary), have, however, made it possible to determine their course accurately, and this has been indicated in the maps annexed to Parts I.–III. of the work by the present writer on the 'Classical Topography of the Roman Campagna,' and will be dealt with fully before long in a special work, which will also be illustrated with drawings and photographs, showing the more important remains of the aqueducts along the whole extent of their course.

WEDNESDAY, SEPTEMBER 9.

The following Papers and Reports were read:—

1. *Notes on an Ancient Land Surface in a River Terrace at Ipswich and on Palæoliths from a Gravel Pit in the Valley of the Lark.* By Miss Nina F. Layard.

At the junction of the river Gipping with the estuary of the Orwell gravelly sands are superimposed on the original red river gravels, but separated from them by a black band varying in thickness from three inches to a foot. This band represents an old land surface which is largely composed of decayed animal matter. In this band the following remains have been found: teeth and bones of a large horse, bones and antler of red deer (*Cervus Elaphus*), large tusk, also tooth and bones of mammoth, bones of *Bos primigenius*, teeth and part of jaw of wolf (*Canis lupus*), proximal end of radius of bear with part of a claw, part of the sternum of a bird, and the shaft of humerus of an herbivorous mammal which has been gnawed. Flint implements were discovered in connection with these remains: a well-worked scraper with a number of flakes; and two small pointed tools of the Abbeville type. These remains were fully 30 feet below the present surface.

The implements from the valley of the Lark were mostly found at a depth of 18 feet, in coarse gravels, which are in some parts of a deep red colour, in others inclining to light yellow. The tools are much rolled, and many have a whitish patina. Comparing these palæoliths with those found at Foxhall Road, Ipswich, the most notable differences are the generally rougher workmanship and the prevalence of flint cores of considerable size, from which knives have been struck. No examples of these cores from East Anglia are included in the British Museum collection, and they do not appear to have attracted much attention in England. Comparing them with the cores from Pressigny and the banks of the Indus in Upper Sindh, it will be seen that the examples from Suffolk are of a much rougher type. Should it be found that cores are usually absent from sites which produce flint tools of the Foxhall Road type, it may be possible to recognise a distinction between knife-making tribes and tribes which had not discovered the art of making long blades.

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2. *Report on the Age of Stone Circles.*—See Reports, p. 400.

3. *Tenth Report on the Lake Village at Glastonbury.*
See Reports, p. 414.

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4. *Report on the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.*—See Reports, p. 419.

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5. *Cup- and Ring-markings.*
By Rev. H. J. DUKINFIELD ASTLEY, *M.A., Litt.D.*

Attention was first publicly called to cup- and ring-markings by Sir James Simpson in his book 'Archaic Sculpturings of Cups, Circles, &c., on Rocks' in 1867, although Sir J. Gardiner Wilkinson claimed to have observed them as far back as 1835. These marks are of wide distribution, archaic examples being found on megalithic monuments, the stones of chambered tumuli, stone kists, and on rocks and boulders in many parts of Great Britain, in Ireland, on the Continent in France, Spain, Italy, and Scandinavia, in China, India, and in North and South America. As examples among modern savages may be instanced those found in Australia, in Fiji, Easter Island, and other parts of the Pacific, as well as certain parts of Africa.

Various theories as to the origin and meaning of these marks have been advanced; these may be grouped according as the explanations are based on (1) religion—sun worship, serpent worship, mithra worship, &c.; (2) signs—dials, maps, plans of villages, a form of writing.

It was suggested that cup- and ring-marks are connected with totemism, being analogous to the designs on the *churinga* of the Arunta, and are to be assigned to a similar stage of primitive society and a corresponding process of primitive psychology.

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6. *Report on Classifying and Registering Megalithic Remains in the British Isles.*—See Reports, p. 341.

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7. *On the Classification of the Megalithic and analogous Prehistoric Remains of Great Britain and Ireland.* *By* GEORGE CLINCH.[1]

Some reasonable and convenient classification of megalithic and related remains is urgently required because of—

1. The existing confusion of ideas as to the different types; and
2. The special need of some common method of classification in view of the Government's promised action with reference to the 'historical monuments' of England.

The author gave recent examples of grotesque errors on the part of 'local antiquaries' and indicated the pressing need of greater care in the study of megalithic remains.

The classification suggested aims at precision combined with sufficient breadth of scope to permit the inclusion of prehistoric dwellings, hill-side sculptures, and other antiquities not already included in the scheme of the Earthworks Committee of the Congress of Archæological Societies.

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8. *Report on the Preparation of a New Edition of Notes and Queries in Anthropology.*—See Reports, p. 342.

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[1] To be published in full in *Annals of Archæology and Anthropology, Liverpool University.*

9. *Perforated Stone Hammers and Axes.* *By* W. J. KNOWLES

Sir John Evans divides axes into four divisions—

1. Double axes.
2. Adzes or implements with the edges at right angles to the shaft-hole.
3. Axes with the edge at one end only.
4. Axe hammers, sharp at one end and more or less hammer-like at the other.

Perforated hammers he considers to be closely allied to the axe hammers.

All these divisions are well represented in Ireland, and I have examples of all the classes.

I have one fine specimen of the third division of axes, hollowed at the sides, with a raised moulding round the hollows. It is six inches long, and was found in the river Bann while deepening the river over fifty years ago. A description of it is given by Robert McAdam in the 'Ulster Journal of Archæology,' vol. iii., and it is shown in two views, full size, facing p. 234. Reference is made to it in 'Ancient Stone Implements,' 2nd edition, p. 198. The author says it is now in the British Museum. Sir John Evans must have been misled in making this statement, as the specimen is in my possession.

There was found at the same time in the Bann an unfinished specimen with the hole partially bored on each side. The hole, so far as formed, would seem to have been made with a pick or punch. The numerous flint picks found in the bed of the Bann and along its banks would have been suitable for making such borings by hammering the pointed end of the pick into the hole. Quarrymen use 'jumpers' of iron pointed with steel for boring holes for blasting at the present day. The implement now used for boring is different, but the method is the same.

The holes in many of the axes and hammers are wide at the surface of the implement and narrow in the centre. There have been many conjectures as to the method of shafting implements with such holes. Sir John Evans discusses many of them, but I do not see that he mentions the plan adopted by the natives of New Britain, who use a shaft the size of the narrowest part of the hole and fill the wider parts with gum, in which they stick cowrie shells.

The perforated axes have mostly blunted and polished edges. They and most hammers must have been used as mace heads.

Section I.—PHYSIOLOGY.

President of the Section.—J. S. Haldane, M.D., F.R.S.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address:—

The Relation of Physiology to Physics and Chemistry.

In choosing to address you on the relation of Physiology to Physics and Chemistry, I am aware that I have selected a subject which has already been treated from this Chair by more than one distinguished predecessor. My excuse for returning to it again is that it not only possesses deep scientific interest for us all, but that a great deal remains to be said about it.

The majority of physiologists in recent times have expressed more or less clearly the opinion that Physiology is the application to living organisms of the methods and modes of explanation of Physics and Chemistry. It is, in short, Physics and Chemistry applied to the activities of living organisms; so that the only explanations aimed at in Physiology are, or ought to be, physical and chemical explanations. A minority, which is at present a growing one, I think, have either definitely dissented from this view, or have remained unconvinced of its truth. As one of this minority I should like to place before you as shortly as possible what seem to me to be the main reasons of our dissent. Let me add that I have carefully pondered over these reasons during many years of active physiological work.

When we look back on the history of Physiology it seems perfectly evident that physiological progress has been dependent on the progress of Physics and Chemistry. On this point there is no room for doubt. To take only one example, where should we be in the investigation of animal metabolism but for the ideas and experimental methods furnished to us by Physics and Chemistry? We should know next to nothing about respiration, animal heat, nutrition, or muscular and other work. Physiology depends at every turn on Physics and Chemistry, and its future progress will certainly be equally dependent on advances in physical and chemical knowledge. This consideration has, I imagine, weighed very heavily in the minds of those physiologists who have concluded that Physiology is nothing but applied Physics and Chemistry. A further fact which weighs equally heavily is that in spite of diligent search no fact contradicting the fundamental laws of conservation of matter and energy has been discovered in connection with living organisms.

When, however, we ask what progress has been made towards the physico-chemical explanation of physiological processes, we at once enter upon controversy. We may point to advances in some directions, but they are accompanied by the appearance of unforeseen difficulties in other directions. Again, to take animal metabolism as a typical instance, the investigations of the last hundred and twenty years have enabled us to assign ultimate physical and chemical sources to the energy and material leaving the body in various forms. We can assign to such sources the energy of animal heat, muscular work, glandular, nervous, and other activity: also the carbon dioxide, urea, salts, and many other substances which leave the body or are formed within it. All of this new knowledge may be regarded as progress towards a physico-chemical explanation of life.

But there is another aspect to be considered; for side by side with what I have just referred to there has been a different kind of increase of knowledge with regard to animal metabolism. This growth of knowledge relates to the manner in which the passage of energy and material through the body is regulated in accordance with what is required for the maintenance of the normal structure and activities of the body. In Liebig's time, for instance, it was believed that the rate of respiratory exchange was regulated simply by the supply to the body of oxygen and food-material. If one breathed faster, or if the barometric pressure or percentage of oxygen in the air increased, the respiratory exchange was assumed to be also increased, just as ordinary combustion outside the body would be increased by an increased supply of oxygen. If, again, one took in more food it was supposed that the excess went to increase the rate of combustion in the blood (*luxus consumption*), just as a fire is increased when more fuel is supplied. We now know that these assumptions were wholly mistaken, and that the respiratory movements, respiratory exchange, and corresponding consumption of food material in the body are regulated with astounding exactitude in accordance with bodily requirements. If, for instance, the body consumes more proteid, it economises a quantity of fat or carbohydrate equivalent in energy value to the proteid; and from day to day the amount of energy liberated in the body is very steady. With regard to the excretion of material by the kidneys a similar growth in knowledge can be traced. It is scarcely a century since the urine was regarded as equivalent more or less to the liquid part of the blood separated from the corpuscles, which were unable to pass through the very fine capillary tubules supposed to exist in the kidney substance. Gradually, however, we have learnt how extraordinarily delicate is the selective action which occurs in the kidney substance, and how efficiently this selective action maintains the normal composition of the blood. Scarcely a remnant is now left of the old filtration theories. Our ideas of tissue nutrition and growth have undergone a similar change; and it is hard to realise that only about seventy years ago Schwann could put forward the theory that cell formation and growth is a process of crystallisation.

One can multiply instances like these almost indefinitely; but I have, perhaps, said enough to show that if in some ways the advance of Physiology seems to have taken us nearer to a physico-chemical explanation of life, in other ways it seems to have taken us further away. On the one hand we have accumulating knowledge as to the physical and chemical sources and the ultimate destiny of the material and energy passing through the body: on the other hand an equally rapidly accumulating knowledge of an apparent teleological ordering of this material and energy; and for this teleological ordering we are at a loss for physico-chemical explanations. There was a time, about fifty years ago, when the rising generation of physiologists in their enthusiasm for the first kind of knowledge closed their eyes to the second. That time is past, and we must once more face the old problem of life.

Let us first look at the answer given to this problem by many of the older physiologists. Roughly speaking they carried physical and chemical explanation of physiological processes as far as they could, and for the rest assumed that at some point or other the physical and chemical factors are interfered with and ordered in a teleological direction by something peculiar to living organisms—the 'vital principle' or 'vital force.' This theory, if one can call it a theory, had the negative merit that it did not lead physiologists to ignore facts which they could not explain. But in practice the 'vital force' became simply a convenient resting-place for these facts. It was assumed that the vital force could do anything and everything, and that it acts 'from the blue' on physical and chemical processes. Yet its action was admittedly dependent on physical and chemical conditions, such as warmth, the presence of oxygen, &c. In fact no consistent definition was given to the conception of 'vital force.' It consequently never could become a working hypothesis of any value. Chiefly on this account, I think, it practically disappeared from Physiology last century. Yet the class of fact which led to the theory of 'vital force' is now more prominent than ever; and what du Bois Reymond called the 'spectre' of Vitalism meets us at every turn, thinly disguised under such names as 'cell autonomy,' 'vital processes,' &c. It is useless to shut our eyes and deny the existence of this 'spectre.' We must fairly face and examine it.

However difficult it may be to imagine physico-chemical explanations of such processes as respiratory exchange, secretion, muscular activity, &c., there is nothing in the known facts relating to each process taken by itself to preclude the possibility of such explanations. Let us then follow the Euclidian method and assume provisionally that they are nothing but physico-chemical processes. This assumption evidently implies that each of the living cells concerned has a very complex and definite structure varying according to its functions. To take an example, a secreting cell in the kidney may be assumed to have a structure which responds to the stimulus of a certain percentage of urea or sodium chloride in the blood, and reacts in such a manner that energy derived from oxidation is so directed as to perform the work of taking up urea or sodium chloride from the blood and transferring it against varying osmotic pressures from one end of the cell to the other. This mechanism must also be assumed to have the property of maintaining itself in working order, and probably also of reproducing itself under appropriate stimuli, besides also performing various other functions. Its physico-chemical structure must thus be very definite and complex—to an extent which the older physico-chemical theories took no account of. If we look to the cells in other parts of the body we are met with the same necessity for assuming complexities of structure which seem to grow in extent with every advance in physiological knowledge, every discovery of new substances present within or around the cells, every discovery of new physiological reactions.

Let us not lose courage, however, but continue to follow the direction in which our assumption leads. In assuming that the body is an enormously complex physico-chemical structure we have only begun to face the difficulties of our hypothesis: for we have still to consider how this structure can have originated in accordance with the physico-chemical theory of life. The adult organism develops from a single cell, the fertilised ovum. It is certain that this cell does not contain in a preformed condition the structure of an adult organism. The conditions of environment in which any particular ovum develops itself are doubtless indefinitely complex from the physico-chemical standpoint, as indeed is the environment of any particular portion of matter existing anywhere. But these conditions also vary almost indefinitely in the case of different ova, whereas the adult organism to which the ovum gives rise reproduces in minute detail the enormously complex characters of the parent organism. We are thus driven to the assumption that the ovum contains within itself a structure which, given certain relatively simple conditions in the environment, reacts in such a way as to build up step by step, from materials in the environment, the structure of the adult organism. To effect this the germ-cell must have a structure almost infinitely more definite and complex than that of any cell in the adult organism. Difficult as it may be to form any conception of the mechanism of a secreting cell, it is infinitely more difficult to form the remotest idea of that of a germ-cell.

But we are still only at the beginning of the difficulty. The assumed tremendous mechanism of the germ-cell has been developed, together with the whole of the rest of the parent organism and countless other germ-cells, from a previous germ-cell. What must the 'mechanism' of this cell have been? And that of its endless predecessors? We have reached the Euclidian *reductio ad absurdum.*

I might strengthen my argument by referring to the further difficulty over any physico-chemical conception of what occurs in the sexual fusion of the male and female cell, or in the process of partial reproduction after injury, or in the facts established by Driesch and others with regard to the extraordinary reproductive powers of each cell in developing embryos. But I have purposely confined my references to more simple and well-known facts; for the more simply the argument can be put, the better. I confess that as a physiologist I am struck with amazement at the manner in which heredity is often discussed by contemporary writers who endeavour to treat the subject from a mechanistic standpoint. Sometimes, indeed, the germ-cell is acknowledged to be a complicated structure, but at other times it is treated as a 'plasma,' which can be mixed with other 'plasma,' divided, or added to, as if for all the world it were so much treacle! I have tried to place clearly before you the assumptions in connection with heredity which to my mind make the physico-chemical theory of life unthinkable, even if it be tenaciously clung to in connection with those ordinary physiological phenomena where, as already explained, it has proved so disappointing.

Our aim as physiologists is to render physiological phenomena intelligible—in other words, to obtain general conceptions as to their nature. The point now reached is that the conceptions of Physics and Chemistry are insufficient to enable us to understand physiological phenomena. But if so, we need not sit down in despair, for we can look for other working conceptions. Are we justified in doing this? I think we are.

There is a prevalent popular idea that the world as presented to us under the conceptions of Physics and Chemistry is more than our own imperfect conception of reality, and corresponds completely with reality itself. Philosophy has shown us, however, that this idea must be erroneous; for if it were correct, knowledge of such a world would be impossible. This was first clearly pointed out almost two hundred years ago in this city by one of the greatest of Irishmen, George Berkeley, at that time a Fellow of Trinity College.[1] The lesson taught by Berkeley, Hume, and their successors is not that Physical Science is of less value than it appears to be, but that its fundamental hypotheses are only working hypotheses, applicable only so far as they successfully fulfil their purpose. Each different science is thus free to employ whatever working hypotheses may prove most useful in interpreting the order of phenomena with which it deals. We are thus perfectly justified in seeking to find a conception of life which will serve as a better working hypothesis than that of life as a physico-chemical process.

I venture to think that the conception we are in search of lies very near to hand and is indeed in common use, though in a form which has hitherto been too ill-defined for deliberate scientific employment. It is simply the conception of the living organism, which stands, or ought to stand, in the same relation to Biology as the conceptions of matter and energy to Physics, or of the atom to Chemistry. Let me try to give more definition to this conception. A living organism is distinguished by the fact that in it what we recognise as specific structure is inseparably associated with what we recognise as specific activity. Its activity expresses itself in the development and maintenance of its structure, which is nothing but the expression of this activity. Its identity as an organism is not physical identity, since from the physical standpoint the material and energy passing through it may be rapidly changing. In recognising it as an organism we are applying an elementary conception which goes deeper than the conceptions of matter and energy, since the apparent matter and energy contained in, or passing through, or reacting with, the organism are treated as only the sensuous expression of its existence. Even the environment is regarded as in organic relation with the organism, and not as a mere physico-chemical environment. It follows that for Biology we must clearly and boldly claim a higher place than the purely physical sciences can claim in the hierarchy of the sciences—higher because Biology is dealing with a deeper aspect of reality. It must also be the aim of Biology gradually to penetrate behind the sensuous veil of matter and energy which at present seems to permeate the organic world at all points.

Let us now see how the conception just defined can be used as a scientific

[1] *Treatise concerning the Principles of Human Knowledge*, 1710.

working hypothesis. In accordance with it any form of physiological activity is presumably related essentially, and not accidentally, to the other details of activity and structure in the same organism. Stated generally, therefore, the problem of Physiology is not to obtain piecemeal physico-chemical explanations of physiological processes, but to discover by observation and experiment the relatedness to one another of all the details of structure and activity in each organism as expressions of its nature as an organism.

The first step in physiological or morphological discovery is to observe the bare sensuous fact of some detail of physical or chemical change, or of composition or structure, in connection with an organism. It is only, however, when we find that this detail is not accidental that it becomes of biological interest. We can observe its constancy or otherwise in the same organism or similar organisms—that is to say, the constancy of its relations to other details of structure and activity. Or we can by experiment search for the element of constancy when it is at first sight hidden from our view. In so far as we find this, it seems to me that we reach physiological or biological explanation; but evidently the process of reaching it is at any stage in knowledge only imperfectly realised, since new details of activity and structure are constantly being revealed.

Concrete examples will make the matter clearer, and I shall first take as an example the progress of knowledge in relation to animal heat. It was of course common knowledge from early times that in the higher animals a certain amount of warmth in the body is present during life. With the invention of the thermometer the body-temperature could be measured, and its extraordinary constancy observed. When Lavoisier measured the heat-production of an animal, and compared the output of heat with the output of carbon dioxide and disappearance of oxygen in respiration, an immense step forward was taken. This step was in two distinct respects a very great one. In the first place it revealed an element of identity between organic and inorganic phenomena, since heat-production in an animal was shown to be accompanied by chemical changes quantitatively identical with those accompanying heat-production by oxidation outside the body. In the second place, and from the distinctively physiological point of view, it revealed a fundamental relation between heat-production, respiratory exchange, and the consumption of food.

As regards the first of these points I should like to say definitely that I, for one, firmly believe that could we only understand them fully we could bring organic and inorganic phenomena under the same general conceptions. Lavoisier's discovery, like that of Mayer in relation to the sources of muscular energy, was a great advance in this direction. But this is a very different thing from an advance in the direction of rendering life intelligible in terms of physico-chemical conceptions as we commonly understand them. Lavoisier's discoveries did nothing in the direction of reducing to physico-chemical terms the apparent teleological or, as I should prefer to say, 'physiological' element in the phenomena of animal heat.

It is to the second point that I wish to direct special attention at present. Lavoisier's discovery rapidly brought the phenomena of animal heat into direct relation, not only with respiration but with nutrition, circulation of blood, excretion, and other processes; and it was gradually discovered that the maintenance of a constant body-temperature renders physiologically intelligible a large number of phenomena in connection with different bodily activities—for instance, increased metabolism with fall of external temperature, sweating or increased circulation through the skin with muscular work, the relative constancy of metabolism during starvation, and the physiological equivalence of proteid, carbohydrate, and fat in proportion to their energy values. These phenomena are intelligible onthe assumption that warm-blooded animals actively maintain a certain body-temperature, just as they maintain a certain bodily structure and composition. This mode of explanation is not a physico-chemical one, but I venture very confidently to assert that it is a physiological one, and in fact the only kind of explanation which really interests and appeals to a true physiologist. The thread of identity which has been traced through the phenomena just referred to seems to me to have proved a real scientific clue.

As another example I may perhaps be allowed to refer shortly to the regulation of breathing, as this is a subject on which I have recently been working. Current accounts of the clock-like action of the respiratory centre during normal breathing, with the expansion and contraction of the lungs acting as a sort of governor through the vagus nerves, always filled me with suspicion, as it seemed to me that such a regulation was altogether unlike a physiological one. This led me to investigate the matter further, along with Mr. Priestley; and we had the satisfaction of being able to prove that the ventilation of the lungs is actually regulated with exquisite exactness, in such a way as to keep the partial pressure of carbon dioxide in the alveolar air and presumably, therefore, in the arterial blood, constant. In reality, therefore, the lung ventilation is regulated in accordance with the requirements of respiratory exchange; and what seems to be true physiological explanation has been advanced a short stage.

The advance of knowledge with regard to the circulation might be made the text of a similar discourse. By a process of abstraction the circulation of the blood may be regarded as a mere mechanical process, connected only by the accidents of physical structure with other physiological processes. Under the influence of mechanistic theories the blood-pressure and rate of blood-flow through different organs were indeed for long supposed to be the primary determining cause of the physiological activities of these organs, just as the rate and depth of breathing were supposed to determine the consumption of oxygen by the body. Evidence is, however, accumulating on all hands that the blood-supply to various parts, like the air-supply to the lungs, is in reality determined by physiological requirements. In other words, it is a direct expression of the nature of the organism, just as the common-sense idea of life would lead us to expect.

I may pass next to a branch of physiological knowledge which is still in its early infancy. Under the influence of mechanistic ideas Physiology has for long left completely out of account investigation into the formation and maintenance of organic structure. For mechanistic explanations structure had to be assumed, and as a consequence anatomy was left high and dry in a position of helpless isolation. If, however, the real aims of Physiology are those which I have tried to indicate, the separation between Physiology and Anatomy must tend to disappear: for the structure no less than the activity of each part must be determined by its relations to the structure and activities of other parts in the organic whole of the living organism. We can investigate these relations, just as we investigate the connection of secretion with respiratory exchange, circulation, or the composition of the blood; and they must evidently be physiological relations. Our aim is not the hopeless one of giving a physico-chemical explanation of the development and maintenance of organic structure, but simply to discover the physiological relations which determine the structure of each part and its maintenance. Many facts bearing on this subject have recently been brought to light by the application of experimental methods to embryology, and by the study of reproduction of lost or injured parts, and of grafting: also by the study of so-called 'internal secretion' in connection with various organs. It seems clear, however, that we are only at the beginning of a vast development of knowledge in this direction, and that for this development far more refined methods of dealing with the chemistry of the body will be required.

It was in connection with the facts of reproduction and heredity that the difficulties of the mechanistic theory of life were found finally to culminate. For the distinctively biological theory of life, to which I have endeavoured to give some definition, these difficulties do not exist. They are, it is true, not solved; but they are set aside as being due to wrong initial assumptions and therefore purely artificial. The difficulty remains of reconciling the fundamental conceptions of Biology with those of Physics and Chemistry. This is, however, a matter of which the discussion must be handed over to Philosophy, which has many similar matters to deal with. If it is a fundamental axiom that an organism actively asserts or maintains a specific structure and specific activities, it is clear that nutrition itself is only a constant process of reproduction: for the material of the organism is constantly changing. Not only is there constant molecular change, but the living cells are constantly being cast off and reproduced. It is only a step from this to the reproduction of lost parts which occurs so readily among lower organisms; and a not much greater step to the development of a complete organism from a single one of the constituent cells of an embryo in its early stages. In all these facts we have simply manifestations of the fundamental characters of the living organism. The reproduction of the parent organism from a single one of its constituent cells separated from the body seems to me only another such manifestation. Heredity, or, as it is sometimes metaphorically expressed, organic memory, is for Biology an axiom and not a problem. The problem is why death occurs, what it really is, and why only certain parts of the body are capable of reproducing the whole. These questions carry us, at least in part, beyond the present boundary lines of Biology. They involve those ultimate questions which, as has just been pointed out, it is the province of Philosophy to deal with.

To turn to another set of questions, the distinctively biological standpoint in Biology involves a change in what has in recent times become the ordinary attitude towards organic evolution. Since our conception of an organism is different in kind, and not merely in degree, from our conception of a material aggregate, it is clear that in tracing back life to primitive forms we are getting no nearer to what is called abiogenesis. The result of investigation in this direction can only be to extend further the domain of Biology and widen biological ideas. Our aim must be, in short, not to reduce organic to inorganic phenomena, but to bring inorganic phenomena into the domain of Biology.

I am well aware that it will be strongly maintained that the change of front which I have urged as necessary involves the giving up of all real attempt at scientific explanation in Biology. As already explained, this is a philosophical question, and I shall not attempt to deal further with it here. What immediately concerns us as biologists is whether the change of front will further or hinder biological advance, particularly in Physiology. Now the first requisite of a working hypothesis is that it should work, and I have tried to point out that as a matter of fact the physico-chemical theory of life has not worked in the past and can never work. As soon as we pass beyond the most superficial details of physiological activity it becomes unsatisfactory; and it breaks down completely when applied to fundamental physiological problems, such as that of reproduction. Those who aim at physico-chemical explanations of life are simply running their heads at a stone wall, and can only expect sore heads as a consequence. It seems to me that the proposed change of front is only the conscious adoption of a common-sense idea which is somewhat vaguely, perhaps, present in the minds of all men, and which has in reality guided biological advance in the past. This idea, as I have tried to show, is a working hypothesis which actually works, and affords clear guidance for future advance.

I would fain add a few words as to the relation of Physiology to Psychology and Ethics: for this is a subject of deep human interest. We know that at any rate the higher organisms are conscious and intelligent. This fact brings Physiology into touch with a new element in the behaviour of organisms. The subject is far too great a one for me to attempt to discuss here, but I should like to say that it appears to me very clear that just as Biology is something more than Physics and Chemistry, so Psychology is something more than Physiology, with the added assumption that consciousness is tacked on to certain physiological processes, if such a crude conception has any definite meaning. We can, it is true, by a process of abstraction treat sensation from the purely physiological side, as in investigating the physiology of the sense-organs; but this is Physiology and nothing else; for we are leaving out of account the distinctive elements of consciousness. At our present stage of knowledge life is not intelligence, and men or animals as intelligent individuals involve a deeper aspect of reality than Biology deals with. Our fundamental physiological working hypothesis cannot be successfully applied to the phenomena of intelligence, and the sooner and more definitely this is realised the better for Physiology.

In conclusion, let me endeavour to state shortly the main contention which I have endeavoured to place before you. It is that in Physiology, and Biology generally, we are dealing with phenomena which, so far as our present knowledge goes, not only differ in complexity, but differ in kind from physical and chemical phenomena; and that the fundamental working hypothesis of Physiology must differ correspondingly from those of Physics and Chemistry.

That a meeting-point between Biology and Physical Science may at some time be found, there is no reason for doubting. But we may confidently predict that if that meeting-point is found, and one of the two sciences is swallowed up, that one will not be Biology.

The following Papers and Reports were then read:—

1. *Proprio-ceptive Reflexes of the Limb.*
By Professor C. S. Sherrington, *F.R.S.*

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2. *Final Report on the 'Metabolic Balance Sheet' of the Individual Tissues.*
See Reports, p. 436.

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3. *Report on the Effect of Climate upon Health and Disease.*
See Reports, p. 442.

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4. *The Physics of High Altitudes in relation to Climate and Health.*
By Michael C. Grabham, *M.D.*

This paper dealt with the physiological influence of electrical tension in association with tissue change, secretion, and cerebral and nerve stimulation, and associates the lassitude experienced in cloudy humidity and also in the excessive dryness of the easterly currents with the low difference of potentials in the atmospheric electrical charge which prevails in each of these conditions.

The author touched upon the well-known increase of the red corpuscles of the blood in mountain altitudes, and correlates the experiments of Dr. Frankland and Professor Tyndall on combustion and luminosity with his own elimination of the influence of aqueous vapour in these experiments to show that the union of O and C is not lessened in rarefied air, and that the more perfect combustion obtained is due to greater molecular freedom and a lessened pressure-promptness of action compensating for sparseness of particles. Such an influence cannot be overlooked as an exciting stimulus within the human body, for there can be no reason to assign a lesser power of combination to the unrestrained oxygen within the air-cells than it shows in penetrating to the central unburnt gases of the candle-flame.

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5. *Report on the Ductless Glands.*—See Reports, p. 440.

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6. *Certain Factors in the Glomerular Secretion of the Kidneys.*
By Professor A. B. Macallum, *F.R.S.*

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7. *Surface Tension as a Factor in the Distribution of Salts inside the Living Cell.* *By* Professor A. B. Macallum, *F.R.S.*

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8. *The Prevention of Deaths under Anæsthetics.* *By* Frederic W. Hewitt, *M.V.O., M.A., M.D.*

Owing to the steady increase in the number of deaths in connection with the use of anæsthetics for surgical operations, the prevention of these distressing accidents constitutes one of the most pressing questions of the day.

In order that the risks incidental to generalised anæsthesia may be reduced, it is obviously first necessary to study the conditions and circumstances under which anæsthetics are now administered. At the present moment (1) the law permits any person to produce general anæsthesia; (2) many of the examining bodies permit their candidates to qualify without producing evidence of having received instruction in anæsthetics; (3) the anæsthetic departments at our hospitals are in many instances imperfectly and inadequately equipped both in *personnel* and in other respects; (4) anæsthetics, in both hospital and private practice, are frequently entrusted to comparatively inexperienced practitioners; and (5) most of our hospitals publish no records of the anæsthetics administered within them.

Experience has conclusively shown that though anæsthetics are powerful poisons, they may be safely administered provided that those who undertake their administration have been properly educated and trained, and that the principles under which they work, and the methods which they employ, are based upon scientific data. The author referred to the valuable physiological researches of Professor A. D. Waller, and to the work of other physiologists in the direction of regulating the percentage composition of anæsthetic atmospheres. While fully admitting that by percentage methods the risks of anæsthetics may be reduced, it was submitted that the ground must first be cleared by better and wider education, and particularly by instilling into students the absolute necessity of securing a perfectly free and unembarrassed air-way during anæsthetisation. There is no single principle, indeed, the faithful observance of which will ensure safety in every case. It was contended that there are three main principles which must collectively be observed, viz.: (1) the selection of appropriate anæsthetics; (2) the adjustment of the percentage of the anæsthetic gas or vapour to meet the requirements of the case; and (3) the avoidance of the slightest obstruction to the free entry and exit of air throughout the administration. The author discussed the relative importance of the second and third of these principles, and suggested that a considerable step towards the solution of the main question might be achieved if arrangements could be made whereby a committee of physiologists might observe, clinically, the usual modes of onset of difficulties and dangers under anæsthetics. Such a committee would soon appreciate the differences between naso-oral and tracheal anæsthetisation, and the asphyxial effects which may arise in the human subject as the result of naso-oral methods. The author regards the third principle as the most important of the three; for his whole clinical experience, and the examination of the records of a large number of recent fatal cases, kindly placed at his disposal by Dr. F. J. Waldo and Dr. Freyberger, convince him that in the great majority of fatalities under anæsthetics some obstruction to breathing above the trachea has been the immediate cause of death.

The following reforms are urgently needed:—

(1) To make it a penal offence for any person other than a legally qualified medical practitioner to administer an anæsthetic;

(2) To improve and extend the anæsthetic departments of our hospitals by appointing experienced men of the highest academic and professional attainments to the various offices of such departments;

(3) To make a thorough course of instruction in anæsthetics a necessary part of the medical education of every practitioner, and

(4) To require hospital authorities to register every anæsthetic administered within their respective institutions.

It is a matter for great congratulation that the General Medical Council have recently looked favourably upon the more important of these reforms, and it is to be hoped that ere long legislation may be granted in the directions indicated.

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9. *Is Alcohol a Food of Muscle? A Comparison of Chloroform, Ether, and Alcohol. By* Professor A. D. WALLER, *F.R.S.*

Dr. Waller described his method of work. Two frog muscles (Sartorius), each immersed in salt solution contained in two glass tubes, are arranged in one electric circuit, so that they can be stimulated simultaneously and their contractions recorded on two smoked plates fixed each on a small railway-truck moved simultaneously by a clock. A series of normal contractions were first recorded on the smoked plates; then the salt solution was replaced by the same quantity of the liquid to be tested, and the record continued. In this way the effects of a series of alcohols and different strengths of alcohol were compared. It seemed as though alcohol in weak solution of about one per cent. acted on muscle as a food—that is to say, not only calling out the energy there but supplying fresh energy—but the experiments are not conclusive enough to give a definite answer.

By this method, also, the toxicity of chloroform was compared with that of alcohol and ether. The toxic value of one ounce of chloroform is equivalent physiologically to nearly half a gallon of alcohol. More precisely, the order of toxicity is—

1 molecule of chloroform is equivalent to
12 molecules of ether and to
100 molecules of ethyl alcohol.

The object of these latter experiments was to determine the safe administration of chloroform, a continuation of work extending over the last fifteen years.

FRIDAY, SEPTEMBER 4.

Discussion on Mental and Muscular Fatigue.

(i) *Fatigue. By* Dr. W. MACDOUGALL.—See Reports, p. 479.

(ii) *Fatigue. By* Professor T. H. MILROY.

Professor Milroy referred to a special form of fatigue—namely, fatigue to colour, and especially with regard to its effect upon those phenomena which are referred to under the term 'simultaneous contrast.'

Simultaneous contrast requires two fields, an inducing and a reacting field; and the visual sensation derived from a stimulation of the latter is of the nature of that furnished by the colour complementary to the inducing colour.

Two explanations of this have been given, a psychological and a physiological one. The former, formulated by Helmholtz, may be stated in the following way:—

When a small colourless field is included in a coloured one, a false judgment is made as to the nature of the former owing to the observer subtracting from the small central field the colour of the larger coloured field.

The other, a physiological explanation, is that furnished by Hering. He regards the surrounding field as affecting the condition of the central one by producing in it a change of the opposite type to that going on in the general field—spatial induction.

If the reacting field be stimulated originally by the colour which would normally be induced in it by the surrounding or inducing field, then simultaneous contrast is no longer seen until a certain time has elapsed to allow the area again to resume its normal condition. Thus even brief exposure of the eye to red spectral light will prevent the appearance of the red tint in the central field which is surrounded by a larger green field. One may observe the gradual increase in the induced effect as fatigue passes off, but it does not reach its normal degree until some time after the usual signs of fatigue, as shown by the negative after-image, have disappeared.

It is interesting, in the light of Hering's views on the black-white substance, to note the effects of a previous fixation of a central lampblack disc in the green-coloured field. If one examines a patch of black in a spectral green field for a few minutes and then removes the black disc and allows white light to pass through in its place, the induced pink simultaneous contrast-effect is not seen at once, but prior to its appearance one has the sensation of a central white field which slowly, beginning from the periphery, shows the gradual pink colouration of the field.

That is to say, during the period when the excitability of the reacting field has been raised by the previous examination of a black field, the inducing colour does not bring out its normal effect.

This phenomenon is more readily explained on the Hering than on the Helmholtz hypothesis.

(iii) *Some Aspects of Mental Fatigue.* *By* H. SACKVILLE LAWSON.

This paper was concerned with the measurement of mental fatigue by means of the æsthesiometer, which is in reality a modified compass, and has been used in connection with physiological experiments on skin-sensitiveness. Intellectual effort causes an accumulation of waste and poisonous material in the brain-cells. As a result of this there is found a diminished skin-sensitiveness in all parts of the body. Hence the measurement in millimetres of the loss in skin-sensitiveness would appear to be a guide to the mental energy expended; and the principal of the æsthesiometer is to record mental fatigue in terms of this nature.

In conducting these experiments it has been found that fatigue symptoms may or may not have a physiological counterpart. The individual experimented on may *feel tired* and yet be objectively fresh, or, on the other hand, he may feel tired and at the same time find justification for this feeling on physiological grounds.

There is yet another kind of fatigue met with in the victims of that 'roten sin' known to Chaucer as *accidie*, which maketh a man 'hevy, thoughtful, and wrawe' and 'full of slouthe, wanhope, and sompnolence.' Many an accidiose patient feels tired and betrays all the outward casual symptoms of fatigue. And yet a careful reading with the æsthesiometer confirms nothing of these symptoms; indicates, on the contrary, that now, as of old, the best remedy for such 'nerves' is hard work.

The following are some of the kinds of information to be obtained by the systematic use of the æsthesiometer:—

1. How many units of skin-sensitiveness a student may lose without injury.
2. The relative fatigue induced by a study of the various subjects in the school curriculum.
3. Information as to the most correct method of arranging the subjects in the time-table.

The physiological effect on the student of different methods of teaching may also be shown.

Lastly, the differences between physiological and psychical fatigue are rendered evident.

The following fatigue graphs have been drawn:—

1. Primary school student.
2. Primary school teacher.
3. Professor in university.
4. Student in university.
5. Vicar in suburban parish.
6. Private pupil: showing physiological effect on him of different methods of teaching. In all cases readings have been taken over a series of days.

The last part of the paper was concerned with fatigue in Egypt, and the conditions generally which obtain in Mohammedan schools.

Educationists in Egypt regret the prevalence of the memorising system and the unavoidable difficulties of the Fast of Ramadan.

Two graphs are shown of a student in a secondary school in Egypt. The first series of readings were taken before the Fast of Ramadan, the second series during that Fast.

In conclusion it would seem that æsthesiometric measurement not only gives very positive results which are helpful to the educationist, but also, by coming into conflict with subjective opinion, seems to suggest a possible cure for those who are subject to accidie and psychical maladies generally.

The following Papers and Report were then read:—

1. *The Interpretation of the Results obtained from the Study of Cerebral Localisation in the Prosimiæ. By* Professor W. H. Wilson *and* Professor G. Elliot Smith, *F.R.S.*

This research was undertaken seven years ago, with the object of determining whether or not electrical stimulation of the cerebral cortex would yield evidence for the identification of a small sulcus in the brains of certain lemurs, which one of us (G. E. S.), on morphological grounds, had described as the representative of the upper part of the sulcus centralis of monkeys and man. The demonstration by Sherrington and Grünbaum that the sulcus centralis was the caudal limit of the excitable area of cortex gave us a definite criterion to make use of in deciding whether or not a sulcus ought to be regarded as Rolando's furrow. We chose the lemurs for this investigation because the arrangement of the sulci in the members of this sub-order formed the key to the comparison of the fissural plan in all the non-primate mammals with that of the apes and man; the plan formed by the sulci in the lemurs so closely resembled that found in the apes that the identity of most of the furrows was obvious; and, at the same time, the Prosimian arrangement was appreciably nearer to—*i.e.*, more like—that found in the carnivora and ungulata and the other mammalia. Six years ago we stimulated two brains of *Loris gracilis*, employing Sherrington's unipolar method, and found centres for movements of the leg, trunk, arm, and head immediately in front of the position of the coronal suture (of the skull), the two brains being quite devoid of the sulcus x, our supposed upper part of Rolando's sulcus. On examining a series of eight brains of *Loris gracilis* we found in two of them a sulcus x exactly on the line of the coronal suture.

Next year Page May joined us, and with our help he stimulated the brains of two examples of *Lemur macaco*, using the bipolar method.

The motor area was mapped out with the greatest ease, and was found to stop sharply at the sulcus x, thus confirming the view which our anatomical researches had previously suggested. Page May repeated the experiments on another lemur, and examined the distribution of the Betz cells in several specimens. The results were presented to the British Association in 1904 at Cambridge.

The authors then repeated the experiments (using the unipolar method) on three examples of *Lemur mongoz*, and studied the distribution of the Betz cells in lemurs of various species, in *Perodichius, Loris, Nycticebus,* and *Tarsius.*

Since then several writers (Brodmann, Oskar and Cecilie Vogt, Völsch, Halliburton, and Mott) have published accounts of the histological and physiological localisation of the motor cortex in lemurs. There are so many discrepancies in these various statements of fact and inference that we propose to describe the results of our latest work, which thoroughly bears out the account given by Page May in Cambridge four years ago; and we seize the opportunity to emphasise and extend our views regarding the significance of these results.

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2. *The Localisation of the Human Cerebral Cortex.* *By* Professor G. Elliot Smith, *F.R.S.*

Two years ago I demonstrated to the Anatomical Society the ease with which one can map out the surface of the human cerebral cortex into a large number of areas, each of which presents distinctive features (thickness, colour, arrangement and density of the intracortical medullary matter) which are appreciable to the naked eye in fresh material, when cut with a scalpel.

Last year I published charts of the human cerebrum showing the distribution of these various anatomically distinct areas and indicating the causal relationship existing between the situation of various sulci and the borders or the axes of these areas.

Shortly afterward Brodmann published similar maps, based upon the results of the histological examination of the human brain. There is a remarkable agreement between the two series of charts, which becomes more pronounced when it is recalled that Brodmann represents one individual brain as seen flattened out in a fresh condition, whereas I have shown the average condition of a large series, represented on a specimen hardened *in situ.*

But even after eliminating these discrepancies and certain other differences which a comparison of the tests (and not the diagrams only) of the two memoirs will dissipate, there are still some points of disagreement between Brodmann's results and mine. I have made a new investigation of all such points of disagreement and, as the result, present new charts, modified in some respects in accordance with Brodmann's results, but in others retaining my own interpretation.

Brodmann refuses to admit my interpretation of the meaning of the cerebral sulci. But the examination of a large series of brains proves beyond any possibility of error that the vast majority of the cerebral furrows are placed constantly near to or actually at the boundary line between adjoining areas or, in other cases, in the axis of a given territory; in other words, the causal relationship between the sulci and the distribution of the areas is patent.

At the same time there is a considerable range of variation in the case of certain sulci, especially the calcarine. Yet no furrow affords a more striking demonstration of the varied factors which call a sulcus into being and determine its form.

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3. *On certain Features of Retinal Photo-electro Phenomena.* *By* Professor Francis Gotch, *F.R.S.*

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4. *Colour-blindness and Colour-perception.* *By* F. W. Edridge-Green, *M.D., F.R.C.S.*

The theory which I have advanced as an explanation of vision and colour-vision is that light falling upon the eye causes the visual purple to be diffused into the surrounding parts of the retina: that the cones of the retina are insensitive to light but sensitive to chemical changes in the visual purple, which stimulates the end of the cones and causes visual impulses. Then in the impulse itself we have the physiological basis of light and in the quality of the impulse the physiological basis of colour. I consider that the quality of the impulse varies with the wave-length of the light causing the impulse.

Cases of colour-blindness may be divided into two classes, which are quite separate and distinct from each other, though both may be present in the same person. In the first class there is light as well as colour loss. In the second class the perception of light is the same as the normal-sighted, but there is a defect in the perception of colour. In the first class certain rays are either not perceived at all or very imperfectly. Colour-blind individuals belonging to the second class can be arranged in a series. At one end of the series are the normal-sighted, and at the other the totally colour-blind. I have classified the colour-blind in accordance with the number of primary colours which they see in the spectrum. If the normal-sighted be designated hexachromic, those who see five colours may be called pentachromic; those who see four, tetrachromic; those who see three, trichromic; those who see two, dichromic; and the totally colour-blind, monochromic. There are many degrees included in the dichromic class. There may or may not be a neutral band, and this is widest in those cases approaching most nearly to total colour-blindness. The tests I use are three in number: (1) Lantern test; (2) Classification test; (3) Spectrum test. In all these tests the examinee is required to know the names of the primary colours—red, yellow, green, and blue, and matching is not employed. In the spectrum test the examinee is required to point out the commencement and termination of the spectrum, designate the various colours, and show by a special apparatus the size of the different portions of the spectrum which appear to him monochromatic.

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5. *Report on the Electrical Phenomena and Metabolism of* Arum Spadices, See Reports, p. 463.

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6. *The Constitution of Lecithin and other Phosphatives.* *By* Dr. Hugh MacLean.

Lecithin used was obtained from the firm of T. D. Riedel, Berlin, and is sold by this firm under the trade name of 'Lecithol.' This lecithin was split up by means of boiling for different periods with a solution of methyl alcohol saturated with $Ba(OH)_2$: the products of hydrolytic decomposition were then separated off and the choline obtained in as pure a state as possible in the form of choline chloride. This choline chloride was precipitated by platinum chloride and the double salt of chlorine platinum chloride obtained; latter was washed, dried, and weighed, and the amount of choline found was then calculated. In no case did the amount of the double salt obtained correspond to more than 80 per cent. of the theoretical amount calculated on the N present, and in a series of about fifteen experiments the actual average result was only 77·3 per cent.

This loss of over 20 per cent. is accounted for chiefly by the fact that

(*a*) Platinum chloride does not *completely* precipitate choline even in concentrated solution; there is a loss of anything up to 10 per cent.

(*b*) Part of the N remains in the insoluble residue obtained after boiling the lecithin. This varies from 6 to 10 per cent. of the total N.

(*c*) Small losses due to decomposition of choline resulting in the production of volatile products; presence of traces of impurities retarding precipitation; slight losses in general manipulation.

Thus it may be assumed that the above 'lecithol' contains practically all its N in the form of choline.

In lecithin obtained from heart-muscle, however, in which the proportion of N to P was almost exactly as 1 : 1, not more than 40 per cent. of the theoretical amount of choline platinum chloride could be obtained when heated in the same way as above. This, coupled with many other observations, proves (contrary to the general statement advanced by Hoppe Seyler) that in this lecithin at least a great part of the N present *is not combined in the form of choline,* but probably as some other base. Similar experiments prove that the monamino-diphosphatide obtained from heart-muscle (Erlandsen's cuorin) contains *no part of its N* in the form of chloline. Egg lecithin, on the other hand, contains all, or nearly all, its N combined as choline.

In the course of this investigation I have succeeded in separating from eggs a new phosphatide with the ratio of N to P as 1:2. Generally, though not exactly, it corresponds to cuorin obtained from heart-muscle.

7. *The Gastro-intestinal Ganglionic Nervous System. By* Sir James Grant, *K.C.M.G.*

An imperfect nervous impulse points to some abnormality in its conduction, and when the obstruction has been removed the axis cylinder once more conveys the impression. This result has been frequently observed during the application of the electric current through the neurotone.

Nerve action to be of service must be normal in its distribution, hence the marked and rapid improvement in digestive power, in the cases cited, on applying the neurotone over the abdomen. This leads to the impression that the neurotone current applied to the abdominal ganglionic nerve centres brings about a change restoring the function of the medulla of the axis cylinder and re-establishing the free transmission of nerve power and energy. As a result constitutional changes for the better become most marked.

The nervous system plays an important part in the remarkable chemical transmission of food-products through the influence of these ganglionic centres. It is due to improvement in nerve conduction of the gastro-intestinal ganglionic system that the neurotone current is capable of improving digestion and prolonging life when no organic disease is present.

MONDAY, SEPTEMBER 7.

Discussion on Instruction of School Teachers in Physiology and Hygiene. Opened by Professor C. S. Sherrington, *F.R.S.*

The following Reports and Papers were then read :—

1. *Report on the Conditions of Health essential to the Carrying-on of the Work of Instruction in Schools.*—See Reports, p. 458.

2. *On Amyloid. By* Professor A. Kossel.

Professor Kossel gave a description of some work done at his laboratory in Heidelberg by Dr. Mayeda, dealing with the subject of the chemical nature of amyloid. Dr. Mayeda tried to decide the question as to whether this albuminous substance differs from other albuminous substances in its chemical structure. This question is one related to a larger problem—namely, the existence of proteïns of abnormal constitution occurring in pathological conditions.

Differing from Neuberg, who considers the amyloid-proteïn as a proteïn belonging to the histone group, but free from histidin, Dr. Mayeda, in determining the cleavage products of proteïn in normal and amyloid-degenerated organs, found no differences between these two kinds of proteïn, and no similarity with histone. He further showed the presence of histidin. The amyloid was found to be digestible by pepsin in hydrochloric acid, and the digested solution gave no reaction for histopeptone.

The quantitative determination of the cleavage-products gave the following results :—

	Amyloid from spleen.	Amyloid from liver.	Histone.
Ammonia	0·4	0·4	—
Histidine	2·3	2·3	2·3
Arginine	7·7	7·9	14–15
Lysine	2·8	2·6	7·7–8·3

This result was confirmed by the quantitative analysis of the whole organs. Dr. Mayeda divided the proteolytic products obtained from the amyloid-degenerated organs into two fractions by precipitating with zinc sulphate. These fractions showed the same percentage of arginine, histidine, and lysine as the analogous fractions obtained from normal organs.

Up to the present therefore no proof has been furnished that the proteïns found in amyloid degeneration differ in their essential structure from the albuminous substances of the same organ in the normal condition.

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3. *The Relationship of the Pyloric to the Fundic Part of the Stomach.* *By* Dr. E. P. Cathcart.

The present investigation was undertaken in order to discover, if possible, the nature of the relationship between the pyloric and fundic parts of the stomach—*i.e.*, to see whether a stimulus acting on the pyloric part alone brought about the secretion of gastric juice in the fundic part by chemical or nervous agency.

For this purpose two dogs were used, in which the stomachs were divided into two parts—the one part purely pyloric, and the other the whole fundus. Further, one of the dogs had, in addition, a Heidenhain isolated stomach—*i.e.*, one where all nervous connection between the large stomach and the isolated is cut off. Latterly controls were also made on a dog with a Pawlow isolated stomach—*i.e.*, with nervous connections intact.

The method employed was to connect the cannula of the isolated pyloric part with a funnel containing the solution to be tested as regards its stimulating properties. This funnel was raised to a suitable height, so that the pressure on the pyloric part would not be too great. It also permitted of the free movement of the fluid brought about by the fairly energetic contractions of the pyloric part of the muscle wall. The gastric juice secreted in the fundic part was collected from another cannula in connection with this part.

It was found that a large number of very different solutions brought about a flow of gastric juice, the amount secreted varying with different stimulants. Of all the solutions or fluids so far tested the only one which did not bring about a secretion of juice was ordinary 'tap' water. This is a point of some importance, as here, although the contractions of the pyloric part were quite as active as, say, with a solution of Liebig's extract, yet no secretion resulted. Among the solutions tested which gave positive results were Liebig's extract solution, peptone (Chapoteaut) solution, sodium chloride solution, alcohol, and distilled water.

The primary question, however, as to whether the secretion is evoked through chemical or nervous agency has not yet been definitely settled, as, owing to trouble with the animals used, the research had to be interrupted before absolutely conclusive results were obtained.

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4. *Isolation of a Physiologically Active Substance from Peptone.* *By* F. O'B. Ellison, *M.D.*

The number of symptoms produced by injection of peptone seem to indicate more than one active agent. This 'peptone effect' is shown by Pick and Spiro not to be due to the albumoses as such, but to an impurity attached to them and called by them 'peptozyme.' This body was found by them in peptone prepared by acid or peptic digestion, but not in that prepared by tryptic digestion. I undertook the following experiments to ascertain if possible whether this peptozyme or any similar bodies could be removed from Witte's peptone by the action of various solvents.

The following was the method I adopted: 25 grams of Witte's peptone were extracted by means of Soxhlet's apparatus, with about 150 c.c. of ether, chloroform, or commercial benzole, under a reflux condenser for about twenty-four hours. The solvent was then distilled off to a small bulk and allowed to dry completely at room temperature. The solid residue was dissolved in, or rather extracted with, 0·9 per cent. NaCl solution, in which it was only sparingly soluble, and the extract was injected into an anæsthetised dog through the femoral vein.

Contrary to the observations of Nolf, I have found that simple hypodermic injection was ineffective. In the case even of unaltered peptone a hypodermic injection of 0·1 gram per kilo. of body weight produced no effect on blood-pressure, while the same dose given intravenously at once produced the characteristic effect. Control injections were made with unaltered Witte's peptone in doses of 0·1 gram per kilo. Not more than one per cent. of Witte's peptone is soluble in boiling ether, benzole, or chloroform; but up to the present I have not been able to carry out any exact quantitative experiments. Some chemical changes also seem to occur during extraction, as the resulting product is only slightly soluble in water, while the original peptone is completely so.

Experiment I.—Injection of the benzole extract of 50 grams Witte's peptone (10 kilo. dog) = very slight fall of blood-pressure, while the heart's beats became more frequent and diminished in amplitude.

Injection of 1 gram of the portion insoluble in benzole produced a great and rapid fall of blood-pressure.

Experiment II.—The same with chloroform extract. Result, very slight fall of pressure.

Injection of the chloroform insoluble residue and subsequent control injection of Witte's peptone were both negative as regards blood-pressure. A sample of blood remained uncoagulated.

Experiment III. the same as *II.*

Injection of chloroform extract = no fall of pressure. A sample of blood taken immediately after did not coagulate.

Control with Witte's peptone = slight fall of blood-pressure, much less than normal.

I think that the following inferences may perhaps be drawn from the foregoing experiments:—

1. That the substance which causes lowering of blood-pressure is not extracted from peptone by benzole, ether, or chloroform.

2. That a substance which confers immunity from the vaso-dilator effect of peptone injection can be extracted from Witte's peptone by chloroform, but not by benzole.

3. That chloroform extracts from peptone a substance which diminishes the coagulability of the blood.

The amount of these extracts used in the above experiments never amounted to more than 0·5 gram, this being chiefly due to the difficulty of extracting large amounts in Soxhlet's apparatus. The extraction with ether had also to be abandoned, as the tap-water was not cold enough to condense ether in the summer weather.

Fischer's research bids fair to sort out the tangle of complex bodies grouped together as peptones on a sound chemical basis, and if the different constituents could be obtained of definite and constant composition much would thereby be gained towards determining their molecular structure; but meanwhile I hope I have shown that something may also be done in the same direction by proceeding on physiological lines.

5. *The Hæmo-renal Index.* *By* Dr. DAWSON TURNER.

The Hæmo-renal Index is the ratio between the electrical resistance of the blood and the electrical resistance of the urine. Methods of measuring the resistance of the blood and of the urine. In health the index is equal to not less than three or more whole numbers, thus

$$\frac{\text{the electrical resistance of the blood}}{\text{the electrical resistance of the urine}} \; \frac{1000}{250} = 4;$$

but in disease there may be alterations. Value of the method in ascertaining the renal efficiency before a proposed operation. Comparison with other methods. Conclusions.

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6. *Osmotic Growths.* *By* Dr. DAWSON TURNER.

Dr. Dawson Turner exhibited a specimen and photographs of the curious growths which Professor Leduc has produced by the purely physical process of osmosis. An artificial seed of one part of sugar and of two parts of copper sulphate is sown in a solution of gelatine and potassium ferro-cyanide: this seed begins to grow as though it were alive: it may attain a height of one to two feet, and it presents organs analogous to those of vegetables, such as roots, stems, leaves, and terminal organs. Functions which were hitherto considered as characteristic of life, such as (1) nutrition by intussusception, (2) organisation, (3) growth in thickness and in length, are thus realised by purely physical forces, and we are led to conjecture whether these functions in living plants and animals may not be due to the same cause.

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7. *Report on Body Metabolism in Cancer.*—See Reports, p. 489.

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8. *Further Observations on a previously undescribed Tract in the Spinal Cord.* *By* Dr. W. PAGE MAY.

The author demonstrated by means of the lantern the presence in several monkeys of a tract to which he gave the provisional name of the postero-septal tract, which undergoes descending degeneration from the mid brain to the lower thoracic region. In the spinal cord it is well marked, lying symmetrically immediately on either side of the posterior septum and situated slightly nearer the posterior margin than the anterior margin of the posterior columns. This tract was discovered by the speaker just over four years ago, and since then he has succeeded in showing its constant presence in several types of monkeys, and undoubtedly it conveys impulses downwards and is of considerable importance.

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9. *Demonstration of the Cells and Tracts concerned in Paralysis and Recovery from Paralysis.* *By* Dr. W. PAGE MAY.

Dr. Page May gave a demonstration of the various tracts concerned in voluntary movement and in the return of movement after paralysis due to interference by disease or otherwise in certain cerebro-spinal paths. An analysis of these paths was given and included the origin, course, and termination of the pyramidal, rubro-spinal, vestibulo-spinal tracts, and the complex of fibres descending in the anterior columns of the spinal cord. Brief references were also given to the disturbances of movement produced by interference, by disease, or otherwise with the functions of one or more of the above paths. Finally, using the chromatolytic method the author showed lantern specimens of the cells which give origin to the above-mentioned tracts in various animals, including those of the cat, lemur, monkey, and chimpanzee.

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10. *The Action of Two Sera on a Carcinoma occurring in Mice.* *By* C. E. Walker.

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11. *The Biological Method of Differentiating Blood-stains.* *By* Professor E. J. McWeeney, *M.A.*, *M.D.*

The method referred to is that known as the Precipitin Test. It is a particular case of the general law that the animal organism reacts to the introduction of foreign substances of high molecular complexity by the production of specific anti-bodies. The most satisfying explanation of this phenomenon hitherto is the now well-known 'Side-Chain' theory of Ehrlich. The foreign substance injected is known as the Anti-gen, and may consist of albumen, toxin, or formed elements (blood-cells or the like). In the present case the anti-gen is albumen derived from some animal and present in its serum, while the anti-body is called a precipitin, because, when brought in contact with specific anti-gen, it manifests its antagonism by the production of an opalescence which speedily thickens into a flocculent precipitate. As this only occurs (save in the case of very closely allied species) with the specific anti-gen, the method affords a reliable means of determining the species of animal from which a given specimen of serum or of blood-stain is derived. Originally applied by the late Walter Myers about the year 1900 to the differentiation of the various kinds of egg- and serum-albumen, the reaction was used on an extensive scale by Nuttall in his fundamental work on blood-relationship, and was applied first in Germany to the purposes of the medical jurist by Uhlenhuth, Wassermann, and Schütze.

Since then the value of the precipitin test as a means of determining the origin of blood-stains occurring on articles of clothing, surfaces, &c., in cases of murder and other medico-legal inquiries has received State recognition in most civilised countries. So far as the writer is aware, however, the method has not been utilised by the Home Office in England, and this is his principal reason for coming forward with the present paper. In Ireland when the advantages of the method were first brought under the notice of the Crown authorities just six years ago by the present writer they received immediate recognition, and the writer has been employing the test for the past five years in medico-legal practice with most satisfactory results. A few words as to technique. The animals used for producing the precipitin are rabbits. As human anti-gen the writer uses ascitic fluid or pleural effusion, aseptically collected where possible, otherwise stored over chloroform. The injections are intravenous, about 5 to 7 cc. being administered at intervals of four or five days. After eight to ten such injections, the animal usually yields a satisfactory anti-serum, giving a distinct zone of opalescence when brought in contact with human serum diluted to 1 in 500. After further treatment the reaction appears with dilutions of 1 per 1,000, and even 1 per 10,000. During the immunisation the power of the serum is tested from time to time by withdrawing small quantities of blood from the marginal vein of the ear by means of suitably curved pipettes. The serum of domestic animals can of course be always readily procured for injection, but suitable anti-gen for making anti-human serum is not always obtainable save by those in hospital practice. In doing the test, as the quantities of stain extract available are as a rule small, the observations are made in very small test-tubes into which about 50 cmm. of the anti-serum is first placed with a glass capillary, after which about 200 cmm. of the diluted serum or stain-extract are allowed to run slowly down the side of the tube so as to form a distinct line of demarcation. The liquids must be absolutely clear. The writer makes his observations at room-temperature, and extends them over a period of four hours. Controls are absolutely indispensable and must on no account be omitted. Working on these lines the writer has obtained most convincing results in every case. The chief sources of error are the so-called mammalian reaction, and the fact that the blood of animals of closely related species is often found to yield reciprocal or group reactions. But these sources of error may be avoided by using only high potential anti-sera, reacting with the anti-gen in a dilution of not less than 1 per 1,000, and by a careful system of controls. The precipitin test, more especially if completed by the still more delicate method of complement-fixation, forms an important and valuable addition to medico-legal procedures of analysis.

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12. *The Action of Acid and Alkali on the Growth and Division of Animal and Vegetable Cells. By* Professor B. MOORE *and* Dr. H. E. ROAF.

Cells are very susceptible to changes in reaction of their surrounding medium. Echinus eggs, hyacinths, and newts have been kept in solutions of various acids and alkalis, and mammals have been fed with large quantities of acid and alkaline phosphates. Isolated cells are very susceptible to the action of the surrounding medium, while more complex organisms can modify the effect and protect themselves by neutralising the excess of acid or alkali. Acid shows, even with the weakest strengths, an inhibiting effect on all growth, the nuclei disappear, and the cells degenerate. With hyacinth rootlets the cell walls become enormously thickened, and the cells themselves become swollen. Japanese newts become lethargic in acid phosphate, thus showing a similar inhibitive effect. Alkali, although also causing stoppage of growth at quite low concentrations, shows with still weaker strengths a stimulating effect. Echinus eggs and hyacinth rootlets show increased cell-division, and, with increased strength of alkali before inhibition occurs, the divisions appear to become irregular. Japanese newts show hyperexcitability, thus pointing to increased and disordered action of the cells. Mammals, with large doses of either acid or alkaline phosphates, show degenerative lesions, but the actual effect of acid or alkali is probably masked by excretion and neutralisation. The 'reactivity' of mammalian blood serum can be altered by large doses of phosphates.

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13. *Changes in the Pituitary after Thyroidectomy. By* Dr. P. T. HERRING.

TUESDAY, SEPTEMBER 8.

Joint Meeting with Section D.—See p. 741.

The following Paper was afterwards read :—

A Review of the Tuberculosis Crusade in Ireland. By Sir ROBERT E. MATHESON.

Section K.—BOTANY.

President of the Section.—F. F. Blackman, M.A., D.Sc., F.R.S.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address:—

The Manifestations of the Principles of Chemical Mechanics in the Living Plant.

The Uniformity of Nature.

Among the phenomena of nature Man finds himself to be one ot medium magnitude, for while his dimensions are about a billion times as great as those of the smallest atoms that compose him they are also about one billionth part of his distance from the centre of his solar system.

From the vantage point of this medium magnitude the man of science scans eagerly the whole range of natural phenomena accessible to him with a strenuous desire for unity and simplification.

By the unwearying study of special sections of this long front of natural phenomena special guiding principles have been detected at work locally. No sooner has this been accomplished than, in obedience to this desire for continuity throughout, such principles have been freely extended on either side from the point of discovery.

Thus, the theory of probability, which dealt at first with so limited an occupation as drawing white and black balls out of an opaque bag, now is known as the only determinable factor in such remote things as the distribution of the duration of human lives and the effect of concentration of the colliding molecules in a solution upon the rate of their chemical change. Again, the principle of evolution discovered among living things has been extended, till to speak of the evolution of societies, of solar systems, or of chemical elements is now but commonplace.

The biologist, with all his special difficulties, has at least the limitation that he is only concerned with the middle range of the interminable hostile front of natural phenomena, and that for him is ordained the stubborn direct attack, leaving the brilliant attempts at outflanking movements to the astronomers on the one wing and the workers at corpuscular emanations on the other.

The atoms and molecules that the biologist has to deal with do not differ from those passing by the same names in the laboratories of chemistry and physics (at least no one suggests this), and their study may therefore be left to others. At the other end of the scale, with astronomical magnitudes we have not to deal, unless indeed we yield to the popular clamour to take over the canals on Mars as phenomena necessarily of biological causation.

In the study of that particular range of phenomena which is the special allotment of the physiologists, animal and vegetable, we have had ever before us the problem of whether there is not here some discontinuity in nature; whether the play of molecular and atomic forces occurring outside the living organism can ever account for the whole of the complexity and correlation of chemical and physical interactions demonstrable within the living structure.

As yet we are of course far from any answer to this question, and no one in a scientific assembly like this will call upon us for prophecies. Yet the subject to which I shall devote my Address has a bearing upon this question. I propose to consider a particular aspect of the relation of chemical changes in a test-tube to those taking place in a living growing plant, and this in the spirit of one who craves for continuity throughout natural phenomena.

The point of view from which the chemist regards the reaction taking place in his test-tube has undergone a change in the last twenty years, a change bringing it more into uniformity with that of the biologist. No longer content with an equation as a final and full expression of a given reaction, the chemist now studies with minutest detail and with quantitative accuracy the progressive stages of development of the reaction[1] and the effect upon it of varied external conditions, of light, temperature, dilution, and the presence of traces of foreign substances.

Perhaps it is too much to believe that this, as it were physiological, study of each reaction is the effect of some benign irradiation from the biological laboratory. At least, however, it is true that it is the modern study of 'slow' chemical reactions which has made all this possible, and the living organism consists almost entirely of slow reactions. The earliest studied chemical reactions, those between substances which interact so quickly that no intermediate investigation can be made, did not of course lend themselves to this work, but nowadays whole classes of reactions are known which are only completed hours or days after the substances are initially mixed. To the slow reactions belong all the hydrolytic and dehydration changes of carbohydrates, fats, and proteids that bulk so largely in the metabolism of plants and animals, together with other fermentation changes such as are brought about by oxidases, zymases, and enzymes in general. This precise quantitative study of chemical reactions has been developing with remarkable acceleration for some twenty-five years, till it is grown almost into an independent branch of science, physical chemistry. This is sometimes called 'general chemistry' because its subject is really the fundamental universal laws of the rate of chemical change, and these laws hold through all the families, genera, and species of chemical compounds, just as the same physiological laws apply to all the different types of plants.

Now if these laws are fundamental with all kinds of chemical change they must be at work in the living metabolic changes. If the chemical changes associated with *protoplasm* have any important factor or condition *quite different* from the state of things which holds when molecules react in aqueous solution in a test-tube, then it might happen that the operation of these principles of physical chemistry would be obscured and not very significant, though it is inconceivable that they should be really inoperative.

My present intention, then, is to examine the general phenomena of metabolism in an attempt to see whether the operations of these quantitative principles are traceable, and if so how far they are instrumental in giving a clearer insight into vital complexity.

The Dominance of Irritability in Physiology.

I think that certain manifestations of these principles are indeed quite clear, though not generally recognised, and that this neglect is largely due to the dominance of what our German colleagues call 'Reizphysiologie'—the notion that *every* change in which protoplasm takes part is a case of the *'reaction' of an*

[1] Modern research has made it clear that reactions conventionally represented by complex equations of many interacting molecules really take place in a succession of simple stages, in each of which, perhaps, only two molecules interact.

'irritable' living substance to a 'stimulus.' Now this general conception of protoplasmic irritability, of stimuli and reactions was, of course, a splendid advance, the early development and extension of which we owe largely to our veteran physiologist Professor Pfeffer of Leipzig. Great as is the service it has rendered to many departments of botany, yet in one direction, I think, it has overflowed its legitimate bounds and swamped the development of the physical-chemical concepts which I shall indicate later on. The great merit of the 'stimulus and reaction' conception is that it supplies a very elastic general formula for the sort of causal connection that we find occurring in all departments of biology; a formula which allows the phenomena to be grouped, investigated, and formally expounded, whether they be the temporary turgor-movements of 'sensitive' plants, the permanent growth movements of tropistic curvatures, or the complex changes of plant-form and development that result from present and past variations of external conditions.

The strength and the weakness of the conception lie in its extraordinary *lack of particularity.* When an irritable cell responds to a stimulus by a reaction nothing is implied about the mechanism connecting the *cause and the effect,* and nothing even about the relative magnitudes of these, but all this is left for special research on the case under consideration. The one natural chain of cause and effect that is recognised to be outside this comprehensive category is that rather uncommon one in which a definite amount of energy of one kind is turned into an equivalent definite amount of energy of another. Here we have a direct 'equation of energy,' whereas in a reaction to a stimulus we are said to have typically an 'unloosing' effect—a liberation of potential energy by a small incidence of outside energy, as in the classical analogies, drawn from completely comprehended non-living things, of a cartridge exploded by a blow, or the liberation into action of a head of water by the turning of a tap.

So elastic a conception may be easily stretched to fit almost any sequence of phenomena with the apparent closeness that argues a bespoken garment. We must therefore be critically on our guard against cases of such sartorial illusion.

The Principles of Chemical Mechanics.

That my consideration of particular cases may be intelligible it seems necessary that I devote a few minutes to outlining the four quantitative mechanical principles which govern every single chemical reaction, though much that I have to say has been drawn from elementary books on physical chemistry.

These four principles are concerned with (1) the nature of the reaction in question; (2) the amount of reacting substances that happen to be present; (3) the temperature at which the reaction is taking place; and (4) the influence of catalysts upon the reaction.

For the moment we will confine ourselves to the first two matters, and assume that catalysts are absent and the substances at constant temperature.

(1) The first principle that we have to consider is that which declares that no chemical reaction is really instantaneous, though the interaction of substances is often so fast that a direct measurement of its rate cannot be made; and, further, that every reaction has its own *specific reaction-velocity* which distinguishes it from other reactions. This is expressed by giving to each particular reaction a numerical *velocity-coefficient* which is low or high proportionally as the reaction slow or quick.

(2) This coefficient only expresses the actual experimental velocity when the reacting substances are present in *unit* concentration, because difference of concentration is just the most important factor controlling the actual reaction-velocity.

If a solution of a substance A of unit concentration is undergoing change, then to keep this reaction going at its present rate fresh amounts of A must be added continually just to equal the amount removed by the reaction and so keep the substance up to unit concentration. The amount of A that had to be added thus per unit time would give an exact measure of the amount being decomposed, *i.e.*, of the specific velocity of this reaction.

If the reaction were started with A at double unit concentration, then twice as much A would have to be added *per* unit time to keep the reaction velocity constant at the double rate it would have started at.

And with higher concentrations proportionally more A would have to be added. It is therefore shown that the amount of chemical change going on in unit time is proportional to the concentration. This is a most fundamental principle of chemical mechanics, known as the *law of mass*, and it may be stated thus: *the amount of chemical change taking place at any time is always proportional to the amount of actively reacting substance (or substances) present.*

To carry out experiments by the procedure given above is in practice very difficult and the velocities of reactions are never measured by the chemist in this way. In a living organism this continual bringing up of new supplies of material to maintain a constant rate of change is the ordinary way of life, but in the chemical laboratory procedure is different. There, definite amounts of substances are initially mixed in a vessel and the reaction is allowed to progress by itself without further additions. In this case there is a continual falling off of the concentration of the substance, and so a corresponding diminution of the actual reaction-velocity.

In this procedure the diminution of the initial amount of substance can be actually measured by withdrawing small samples at intervals of time and analysing them. Let us consider a definite example. Cane-sugar can be hydrolysed, under various conditions, to give two molecules of hexose, according to the equation

$$C_{12}H_{22}O_{11} + H_2O = 2C_6H_{12}O_6.$$

This reaction goes on, though extremely slowly, when an aqueous solution of cane-sugar is kept very hot in a beaker. Suppose we started with, say, 128 grammes dissolved in a litre of water and traced the diminution of this amount down towards zero by withdrawing samples at intervals of time and analysing them. If we plotted the sugar-content of these successive samples against the times when they were taken we should get the curve given in fig. 1. If we call n minutes the time taken for the sugar to diminish from 128 grammes to 64 grammes, we should find that in the second n minutes the sugar had fallen to 32 grammes, after $3n$ minutes to 16 grammes, and so on, the amount halving itself every n minutes. Thus the amounts of cane-sugar hydrolysed in successive equal intervals are 64, 32, 16, 8, 4, 2, 1 grammes, amounts in each case just exactly proportional to the quantity of cane-sugar then remaining in solution, thus exemplifying the law of mass.

Such a curve as A in fig. 1, which changes by a constant multiple for successive units of time (here halving itself every n minutes) is known as a logarithmic curve; the velocity of reaction at any moment is exactly indicated by the steepness of the curve at that moment; the velocity is greatest at first and it declines to almost zero as the curve approaches the horizontal at the end of the reaction.

When instead of the decomposition of a single substance we deal with two dissolved substances, A and B, reacting together, then as *both* of them go on being thus used up, the amount of change must be ever proportional to the mass or amount of A present multiplied by the mass of B present.

There is a special important case when the amount of, say, B is in very great excess of that amount required to unite with the whole of A. Then all through the slow progress of the reaction the amount of B never becomes reduced enough to make appreciable difference to its mass, and it may be considered as practically constant all along. In such a case the rate of the reaction is found to be proportional simply to the amount of A present, and we get again the curve A, fig. 1. Here the amount of A may be considered as a limiting factor to the amount of reaction; B being in such great excess never falls low enough to take a practical part in determining the velocity.

The case of the hydrolysis of cane-sugar in aqueous solution is just such a case. The water itself enters into the reaction, but so little is used up in relation to the enormous excess present that the amount remains practically constant and the rate of hydrolysis of the cane-sugar is determined only by the amount of the cane-sugar present at any moment.[1]

(3) We have now shown how the actual amount of chemical change going on in a solution is determined by the combined effect of (1) the specific reaction velocity and (2) the law of mass. We have next to point out that the specific reaction coefficient is not the same under all circumstances, but is affected by variations of external conditions, always by temperature, and generally by the presence of traces of so-called catalysts.

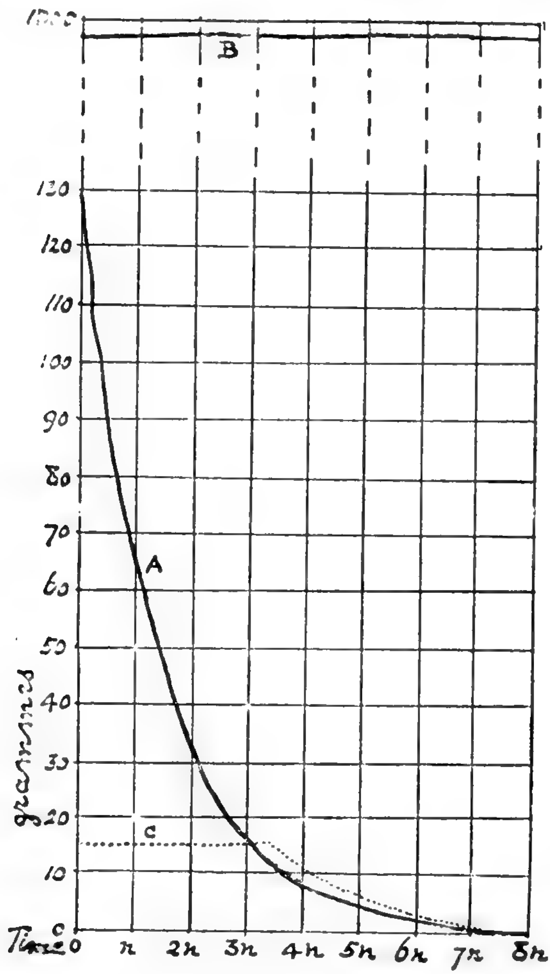

FIG. 1.

The relation to temperature we will postpone, and proceed to consider our hird principle, the acceleration of reaction velocity by *catalytic agents.*

It has long been known that small additions of various foreign substances may have a great effect in increasing the rate at which a reaction is proceeding. Thus this hydrolysis of cane-sugar, so slow with pure water, goes at a fair velocity if a few drops of a mineral acid are added to the solution, while the addition of a trace of a particular enzyme (invertase from plant or animal) enormously increases the rate of change, so that the whole 128 grammes of cane-sugar are soon hydrolysed to hexose. The reaction progresses quantitatively in the same sort of

[1] 128 grammes cane-sugar unite with 6·7 grammes water in hydrolysis, and in our experiment nearly 1000 grammes of water are present.

way as before, giving a logarithmic curve of sugar-content. Indeed the same graphic curve, fig. 1, A, would represent the facts if the value of n were reduced from many hundred minutes to quite a few.

The most striking point about this new state of things is that the added body is not used up by its action, but the acid or enzyme is still present in undiminished amount when the reaction is completed.

Such actions were at first styled 'contact' actions, but are now known as catalytic actions, because we have learned that the catalyst does not work just by contact but by combining with the sugar to form an intermediate addition compound, and that this compound is then split up by the water liberating the catalyst again, but freeing the sugar part, not as cane-sugar, but combined with the water to form two molecules of hexose.

On many chemical reactions, finely divided metals such as platinum and gold have a very powerful catalytic action. Thus platinum will cause gaseous hydrogen and oxygen to unite at ordinary temperatures, and will split up hydrogen dioxide with the formation of oxygen. The intermediate stages in this catalytic decomposition may be summarily simplified to this—

$$H_2O_2 + Pt = PtO + H_2O \quad \text{and} \quad PtO + H_2O_2 = Pt + O_2 + H_2O.$$

Thus the reaction goes on and on by the aid of the appearing and disappearing 'intermediate compound' PtO till at the end the H_2O_2 is all decomposed and the platinum is still present unaffected.

The enzymes are the most powerful catalytic agents known, and most of them are specifically constituted to effect the hydrolysis, oxidation, reduction, or splitting of some definite organic compound or group of compounds containing similar radicals.

Innumerable enzymes have in late years been isolated from the plant-body, so that it would seem that there is one present to catalytically accelerate each of the slow single changes that in the aggregate make up the complex metabolism of the plant.

The law of mass applies with equal cogency to *catalytic* reactions. If twice the amount of acid is added to a solution of cane-sugar (or twice the amount of enzyme) then the reaction velocity is doubled, and hydrolysis proceeds twice as fast. As the catalyst is not destroyed by its action, but is continually being set free again, the concentration of the catalyst remains the same throughout the reaction; while, on the contrary, the amount of cane sugar continually decreases.

If the catalyst be present in great excess the amount of hydrolysis will be limited by the amount of cane-sugar present, and as this is used up so the reaction will progress by a logarithmic curve as in fig. 1, A. In this case B may represent the amount of catalyst. If, on the contrary, there is a large amount of sugar and very little acid or enzyme present, so that the catalyst becomes the limiting factor, then we happen upon a novel state of things; for by the law of mass the rate of hydrolysis will now remain constant for some time till the excess of sugar is so far reduced that it in turn becomes a limiting factor to the rate of change. In this case the velocity curve would consist of a first phase with a straight horizontal line of uniform reaction-velocity leading into the second phase of a typical falling logarithmic curve (see fig. 1, C). These conditions have been experimentally examined by Horace Brown and Glendinning, and fully explained and expounded by E. F. Armstrong in Part II. of the critical 'Studies in Enzyme Action.'[1]

Having now outlined the three fundamental principles of reaction-velocity, the law of mass, and the catalytic acceleration of reaction-velocity, we are in a position to consider the broad phenomena of metabolism or chemical change in the living organism from the point of view of these principles of chemical mechanics.

[1] *Proc. Roy. Soc.*, vol. lxxiii, 1904, p. 511.

THE METABOLISM OF THE PLANT CONSIDERED AS A CATALYTIC REACTION.

Plants of all grades of morphological complexity, from bacteria to dicotyledons, have this in common, that throughout their active life they are continually growing. Putting aside the *qualitative* distribution of growth that determines the morphological form, as a stratum of phenomena above the fundamental one that we are about to discuss, we find that this growth consists in the assimilation of dead food-constituents by the protoplasm with a resulting increase in the living protoplasm accompanied with the continual new formation of dead constituents, gaseous CO_2, liquid water, solid cellulose, and what not. This continual flux of anabolism and katabolism is the essential character of metabolism, but withal the protoplasm increases in amount by the excess of anabolism over katabolism.

Protoplasm has essentially the same chemical composition everywhere, and in the whole range of green plants the same food-materials seem to be required; the six elements of which proteids are built are obviously essential in quantity as building material, but in addition small amounts of Fe, Ca, K, Mg, Na, Cl, and Si are in some other way equally essential. What part these secondary elements play is still largely a matter of hypothesis.

Regarding metabolism thus crudely as if it were merely a congeries of slow chemical reactions, let us see how far it conforms to the laws of chemical mechanics we have outlined.

If the supply of any one of these essential elements comes to an end, growth simply ceases and the plant remains stationary, half-developed. If a *Tropæolum* in a pot be watered with dilute salt-solution, its stomata soon close permanently, and no CO_2 can diffuse in to supply the carbon for further growth of the plant. In such a condition the plant may remain for weeks looking quite healthy, but its growth may be quite in abeyance.

In agricultural experience, in manuring the soil with nitrogen and the essential secondary elements, the same phenomenon is observed when there is a shortage of any single element. If a continuous though inadequate supply of some one element is available then the crop development is limited to the amount of growth corresponding to this supply. Agriculturalists have formulated the 'law of the minimum,' which states that the crop developed is limited by the element which is minimal, *i.e.*, most in deficit. Development arrested by 'nitrogen-hunger' is perhaps the commonest form of this. All this is of course in accordance with expectation on physical-chemical principles. The quantity of anabolic reaction taking place should be proportional to the amount of actively reacting substances present, and if any one essential substance is quite absent the whole reaction must cease. It therefore seems clouding a simple issue and misleading to say of a plant which, from the arrested development of nitrogen-hunger, starts growth again when newly supplied with nitrogen that this new growth is a response to a '*nitrogen stimulus.*' It would appear rather to be only the removal of a limiting condition.

Let us now move on a stage. Suppose a growing plant be liberally supplied with all the thirteen elements that it requires, what, then, will limit its rate of growth? Fairy bean-stalks that grow to the heavens in a night elude the modern investigator, though some hope soon to bring back that golden age with overhead electric wires and underground bacterial inoculations. If everything is supplied, the metabolism should now go on at its highest level, and quantities of carbon, nitrogen, hydrogen, and oxygen supplied as CO_2, nitrates, and water will interact so that these elements become converted into proteid, cellulose, &c. Now this complex reaction of metabolism only takes place in the presence of protoplasm, and a small amount of protoplasm is capable of carrying out a considerable amount of metabolic change, remaining itself undestroyed. We are thus led to formulate the idea that metabolism is essentially a catalytic process. In support of this we know that many of the inherent parts of the protoplasmic complex are catalytic enzymes for these can be separated out of the protoplasm, often simply by high mechanical pressure. We know, too, nowadays that the same enzymes that accelerate katabolic processes also accelerate the reverse anabolic processes.

In time a small mass of protoplasm will, while remaining itself unchanged, convert many times its own weight of carbon from, let us say, the formaldehyde (HCHO) of photosynthesis to the carbon dioxide (CO_2) of respiration.

If metabolism is a complex of up-grade and down-grade changes catalysed by protoplasm we must expect the amount of metabolism to obey the law of mass and to be proportional to the masses of substances entering into the reaction. The case when any one essential element is a limiting factor we have already considered. When all are in excess, then the *amount of the catalyst present* becomes in its turn the limiting factor. Transferring this point of view to the growing plant, we expect to find the limited mass of protoplasm and its constituent catalysts setting a limit to the rate of metabolic change in the extreme case where all the materials entering into the reaction are in excess. When once this supply is available further increase in supplies cannot be expected to accelerate the rate of growth and metabolism beyond the limit set by the mass of protoplasm. This, of course, is in accordance with common experience. The clearest experimental evidence is in connection with respiration and the supply of carbohydrates—this, no doubt, because the carbohydrate material oxidised in respiration is normally stored inside plant-cells in quantity and can be estimated. When the supplies for an internal process have to be obtained from outside, then we have the complications of absorption and translocation to obscure the issue, especially in the case of a higher plant.

Let us first take a case where the carbohydrate supply is in excess and the amount of catalytic protoplasm is small and increasing. Thus it is in seeds germinating in the dark: respiration increases day by day for a time, though carbohydrate reserves are steadily decreasing. Palladine[1] has investigated germinating wheat by analysing the seedlings and determining the increase of the essential (non-digestible) proteids day by day. The amount of these proteids he regards as a measure of the amount of actual protoplasm present. Assuming this to be so, he finds an approximately constant ratio between the amount of protoplasm at any stage and the respiration.

As germination progresses in the dark the supplies of reserve carbohydrate presently fail, and then the respiration no longer increases in spite of the abundant protoplasm. According to our thesis the catalyst is now in excess and the CO_2 production is limited by the shortage of respirable material.

This second type of case was more completely investigated by Miss Matthæi and myself in working on the respiration of cut leaves of cherry-laurel kept starved in the dark. For a time the CO_2 production of these non-growing structures remains uniform, and then it begins to fall off in a logarithmic curve, so that the course of respiration is just like c in fig. 1. We interpret both phenomena in the same way: in the initial level phase the respirable material in the leaf is in excess, and the amount of catalytic protoplasm limits the respiration to the normal biological level; in the second falling phase some supply of material is being exhausted, and we get a logarithmic curve controlled by the law of mass, as much, it would seem, as when cane-sugar is hydrolysed in aqueous solution.

After these two illustrations of the action of the law of mass from the more simple case of respiration we return to the consideration of the totality of metabolic reactions as exemplified in growth.

What should we expect to be the ideal course of growth, that is, the increase of the mass of the plant regarded as a complex of reactions catalysed by protoplasm? Let us consider, first, the simplest possible case, that of a bacterium growing normally in a rich culture solution. When its mass has increased by anabolism of the food material of the culture medium to a certain amount it divides into two. As all the individuals are alike, counting them would take the place of weighing their mass. The simplest expectation would be that, under uniform conditions, growth and division would succeed each other with

[1] *Revue gén. de botanique*, tome viii. 1896.

monotonous regularity, and so the number or mass of bacteria present would double itself every n minutes. This may be accepted as the ideal condition.

The following actual experiment may be quoted to show that for a time the ideal rate of growth is maintained, and that at the end of every n minutes there is a doubled amount of protoplasm capable of catalysing a doubled amount of chemical change and carrying on a doubled growth and development.

From a culture of *Bacillus typhosus* in broth at 37° C. five small samples were withdrawn at intervals of an hour, and the number of bacteria per unit volume determined by the usual procedure. The number of organisms per drop increased in the following series: 6·7, 14·4, 33·1, 70·1, 161·0.[1] This shows a doubling of the mass of bacteria in every fifty-four minutes and is the case actually represented in the strictly logarithmic curve of fig. 2.

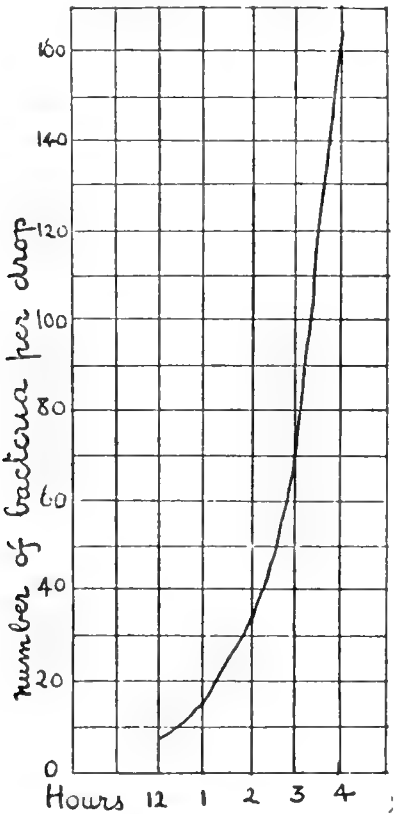

FIG. 2.

We may quote some observations made by E. Buchner[2] of the rate at which bacteria increase in culture media. Bacillus coli communis was grown at 37° C. for two to five hours, and by comparison of the initial and final numbers of bacteria the time required for doubling the mass was calculated. Out of twenty-seven similar experiments a few were erratic, but in twenty cases the time for doubling was between 19·4 and 24·8 minutes, giving a mean of 22 minutes. This produces an increase from 170 to 288,000 in four hours. No possible culture medium will provide for prolonged multiplication of bacteria at these rates.

Cohn[3] states that if division takes place every sixteen minutes then in twenty-four hours a single bacterium 1μ long will be represented by a multitude so

[1] For this unpublished experiment on bacterial growth I am indebted to Miss Lane-Claypon of the Lister Institute of Preventive Medicine.

[2] Buchner, *Zuwachsgrossen u. Wachsthumsgeschwindigkeiten*, Leipzig, 1901.

[3] Cohn, *Die Pflanze*, Breslau, 1882, p. 438.

large that it requires twenty-eight figures to express it, and placed end to end they would stretch so far that a ray of light to travel from one end to the other would take 100,000 years. The potentialities of protoplasmic catalysis are thus made clear, but the actualities are speedily cut short by limiting factors.

For a while, however, this ideal rate of growth is maintained. At the end of every n minutes there is a doubled amount of protoplasm present, and this will be capable of catalysing twice the amount of chemical change and carrying on a doubled amount of growth and development. This is what common-sense and the law of mass alike indicate, and is exactly what this logarithmic curve in fig. 2 expresses.

This increase of the amount of catalytic protoplasm by its own catalytic activity is an interesting phenomenon. In Section K we call it growth, attribute it to a specific power of protoplasm for assimilation (in the strict sense), and leave it alone as a fundamental phenomenon, but are much concerned as to the distribution of the new growth in innumerable specifically distinct forms. In the Chemical Section they call this class of phenomenon 'autocatalysis,' and a number of cases of it are known. In these a chemical reaction gives rise to some substance which happens to catalyse the particular reaction itself, so that it goes on and on with ever-increasing velocity. Thus, we said that free acid was a catalyst to the hydrolysis of cane-sugar; suppose now that free acid were one of the products of the hydrolysis of sugar, then the catalyst would continually increase in amount in the test-tube, and the reaction would go faster and faster. Under certain conditions this actually happens. Again, when methyl acetate is hydrolysed we normally get methyl alcohol and free acetic acid. This free acid acts as a catalyst to the hydrolysis, and the rate of change continually accelerates. Here, if the supply of methyl acetate were kept up by constant additions, the reaction would go faster and faster with a logarithmic acceleration, giving a curve of velocity identical with fig. 2, A.

For a clear manifestation of this autocatalytic increase in the plant it is, of course, essential that the supply of food materials to the protoplasm be adequate.

Another case where we might look for a simple form of this autocatalytic increase in the rate of conversion of food materials to anabolites would be in the growth of a filamentous alga, like Spirogyra. Here, as in the bacterium, all the cells are still capable of growth. In this case the food-material needed in greatest bulk is carbon, which has to be obtained by photosynthesis. Some experiments have been started in the Cambridge Laboratory on the rate of growth of Spirogyra in large tubs of water kept at different temperatures and with varying facilities for photosynthesis and metabolism. Under rather depressing conditions the Spirogyra took several days to double its weight—a rate of metabolism out of all comparison slower than that of bacteria. Experiments on these lines, with the different food materials as limiting factors, should give instructive results.

We turn now to consider the growth of a flowering plant. Here conditions are more complex, and we know that at the flowering stage or end of the season the growth diminishes considerably. This difference from a simple alga or bacterium we can only regard as a secondary acquisition in relation to the external conditions—either a reaction to a present external stimulus or to the memory of past stimuli. In a flowering plant, too, all the cells do not continue to grow; many cells differentiate and cease to grow and also some of the groups of meristem remain dormant in axillary buds. Clearly the growth curve cannot continue to accelerate logarithmically, and in later phases it must tail off; the 'grand period' which growth is said to exhibit is another way of stating this. It will, however, be of great interest to us to see what will be the form of the curve of growth during the early period of development.

The importance of this class of work has been realised in Geneva, and detailed work is now being done under the inspiration of Professor Chodat [1] in

[1] A. Monnier, *Les matières minérales et la loi d'accroissement des végétaux*, Geneva, 1905; N. Déléano, *Le rôle et la fonction des sels minéraux dans la vie de la plante*, Geneva, 1907. See also the independent work of Tribot, *Comptes rendus de l'Acad. des Sciences*, October 14, 1907.

which the curve not only of growth (fresh weight) but of the uptake of all the separate important elements in selected plants is being carefully followed.

With plants grown in the open, climatic disturbances must occur. We shall therefore figure a curve for the fresh weight of a maize plant grown in water-culture. This is prior to the Geneva work, and due to Mlle. Stefanowska,[1] who has studied also the growth-curves of small animals. The first phase of the curve, lasting some fifty days, shows strictly uniform acceleration, doubling the weight of the plant every ten days (fig. 3). The precise external conditions are not stated.

In spite of the morphological complexity the autocatalytic reaction of growth is apparently not checked by inadequate supplies before the plant enters rather suddenly upon the second phase. Here, from the present point of view, we consider that the progress of growth is interrupted, not by the primary physical-chemical causes, but by secondary causes, presumably to be classed in the category of stimulus and reaction.

The numerous curves for the accumulation of different organic and mineral constituents worked out for barley and buckwheat at Geneva are of similar form, but do not keep up the uniform rate of doubling so well as does the curve of total fresh weight.

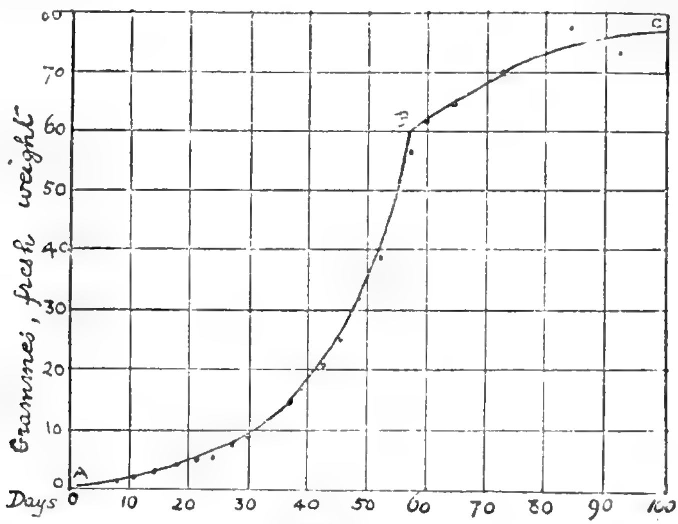

FIG. 3.

In this connection the tall and dwarf forms of the same plant present an interesting problem, and some experiments have been started on sweet peas at Cambridge. At the time of germination the seedlings weigh about the same, whereas at the end of the season the weight of a tall plant is many times that of a dwarf 'cupid' growing alongside under similar conditions. Is the difference due to a less vigorous autocatalysis in the dwarf form, so that throughout its growth it takes a greater number of days to double its weight? Construction of the curves of growth through the season will show whether it is this or some other alteration in the form of the curve.

I now propose to say a few words about one last point in connection with growth considered as a phenomenon of catalysis before passing on to deal with the effects of temperature.

Of the metallic elements that are essential for the growth of plants some occur in such minute quantities that one can only imagine their function is catalytic. If iron, for instance, played any part in metabolism which involved its being used up in any building material or by-product of metabolism, then a

[1] Stefanowska, *Comptes rendus de l'Acad. des Sciences*, February 1, 1904

larger amount than actually suffices should be advantageous. If its function is catalytic the iron would go on acting indefinitely without being consumed, and so a minute trace might serve to carry out some essential, and even considerable, sub-section of metabolism.

Elements like manganese, magnesium, and iron are often associated with non-vital catalytic action, and a preparation of iron has recently been quantitatively investigated which seems to have literally all the properties of an organic oxydase from plant tissues.[1]

As long ago as 1869 Raulin observed that traces of unessential salts, in particular those of zinc, added to the culture medium in which he grew the fungus *Sterigmatocystis* caused a rapid acceleration of the growth rate. The time that the mycelium took to double its weight was now reduced to a half or even a third. This continued enormous effect of so small a trace of substance is possibly to be regarded as an added catalyst to the normal protoplasmic apparatus. This sort of effect is currently labelled 'chemical stimulation' and has been interpreted as an attempt of the fungus to grow away from an unpleasant environment. To me it looks as if such chemical simulation were really another example of the injudicious extension of the concept of stimulus and reaction.

This effect of zinc upon the growth of mycelium has recently been verified and extended by Javillier,[2] who has made comparative cultures with increasing doses of zinc salt. He grew *Sterigmatocystis* for four days at 34° C. in media with graded additions of zinc salts. As the graphic representation shows, he finds a

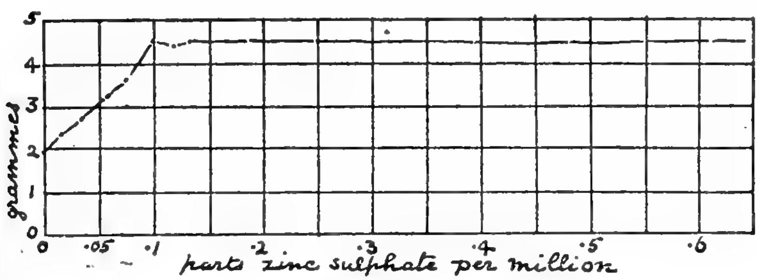

FIG. 4.

continuous regular increase of the number of grammes of final dry weight with doses up to 0·00001 per cent., and then no greater but an equal effect up to 100 times as large a dose.

This form of curve with uniform rise at first, abruptly changing to a level top, suggests, as I have pointed out elsewhere,[3] the cutting-off of the primary rising effect by a limiting factor. In this case presumably the limit set by some other sub-section of the metabolism has been attained.

Acceleration of Reaction-velocity by Temperature.

We now turn to consider the fourth and last of the principles of chemical mechanics which we might expect to find manifested in metabolism.

It is a universal rule that rise of temperature quickens the rate at which a chemical reaction proceeds. Of course in some rare conditions this may not be obvious, but be obscured by superposed secondary causes; but almost always this effect is very clearly marked.

Further, the nature of the acceleration is a peculiar one. Rise of temperature affects nearly all physical and chemical properties, but none of these is so greatly affected by temperature as is the velocity of chemical reaction. For a rise of 10° C. the rate of a reaction is generally increased two or three fold, and this has

[1] J. Wolff, 'Des péroxydiastases artificielles,' *Comptes rendus de l'Acad. des Sciences*, June 9, 1908.

[2] *Comptes rendus de l'Acad. des Sciences*, December 1907.

[3] 'Optima and Limiting Factors,' *Annals of Botany*, vol. xix. April 1905

been generalised into a rule by van 't Hoff. As this increase is repeated for each successive rise of 10° C. either by the same factor or a somewhat smaller one, the acceleration of reaction-velocity by temperature is logarithmic in nature, and the curve representing it rises ever more and more steeply. Thus keeping within the vital range of temperature a reaction with a temperature factor of $\times 2$ per 10° C. will go sixteen times as fast at 40° C. as at 0° C., while one with a factor of $\times 3$ will go eighty-one times as fast.

This general law of the acceleration of reactions by temperature holds equally for reactions which are being accelerated by the presence of catalysts. As we regard the catalyst as merely providing for the particular reaction it catalyses, a quick way round to the final stage by passing through the intermediate stage of forming a temporary addition-compound with the catalyst itself, so we should expect rise of temperature to accelerate similarly these substituted chemical reactions.

If this acceleration is a fundamental principle of chemical mechanics it is quite impossible to see how vital chemistry can fail to exhibit it also.

Acceleration of Vital Processes by Temperature.

At present we have but a small number of available data among plants to consider critically from this point of view. But all the serious data with which I am acquainted, which deal with vital processes that are to be considered as part of the protoplasmic catalytic congeries, do exhibit this acceleration of reaction-velocity by temperature as a primary effect.[1]

Let us briefly consider these data. On the katabolic side of metabolism we have the respiratory production of CO_2, and opposed to it on the anabolic side the intake of carbon in assimilation.

As a measure of the rate of the metabolic processes constituting growth we have data upon the division of flagellates; and finally there is the obscure process of circulation of protoplasm.

The intensity of CO_2 production is often held to be a measure of the general intensity of metabolism, but any relation between growth-rate and respiration has yet to be clearly established. Our science is not yet in the stage when quantitative work in relation to conditions is at all abundant; we are but just emerging from the stage that chemistry was in before the dawn of physical chemistry.

Taken by itself the CO_2-production of an ordinary green plant shows a very close relation with temperature. In the case of the cherry-laurel worked out by Miss Matthæi and myself the respiration of cut leaves rises by a factor of 2·1 for every 10° C. (See fig. 5, Resp.) This has been investigated over the range of temperatures from 16° C. to 45° C. At this higher temperature the leaves can only survive ten hours in the dark, and their respiration is affected in quite a short time, but in the initial phases the CO_2 output has the value of 0·0210 gr. per hour and unit weight of leaf, while at 16°·2 C. the amount is only 0·0025 gr. CO_2. Thus the respiration increases over a range of tenfold with perfect regularity solely by increase of temperature. No reaction in a test-tube could show less autonomy. At temperatures above 45° C. the temperature still sooner proves fatal unless the leaf is illuminated so as to carry out a certain amount of photosynthesis and compensate for the loss of carbon in respiration. Thus, with rising temperature, there is at no time any sign of an optimum or of a decrease of the intensity of the *initial* stage of respiration.

Here, then, on the katabolic side of metabolism we have no grounds for assuming that 'temperature-stimuli' are at work regulating the intensity of protoplasmic respiration, but we find what I can only regard as a purely physical-chemical effect. The numbers obtained by Clausen[2] for the respiration of seedlings and buds at different temperatures indicate a temperature coefficient of about 2·5 for a rise of 10° C.

[1] A collection of twenty cases, mostly from animal physiology, by Kanitz (*Zeits. für Elektrochemie*, 1907, p. 707), exhibits coefficients ranging from 1·7 to 3·3.

[2] *Landwirtschaftliche Jahrbücher*, Bd. XIX, 1890.

To this final process of katabolism there could be no greater contrast than the first step of anabolism, the assimilation of carbon by the protoplasm as a result of photosynthesis. We must therefore next inquire what is the relation of this process to temperature.

This question is not so simple, as leaves cannot satisfactorily maintain the high rate of assimilation that high temperatures allow. The facts of the case were clearly worked out by Miss Matthæi,[1] the rate of assimilation by cherry-laurel leaves being measured from $-6°$ C. to $+42°$ C. Up to 37° C. the curve rose at first gently and then more and more steeply, but on calculating out the values it is found that the acceleration for successive rises of 10° C. becomes less and less. Between 9° C. and 19° C. the increase is 2·1 times, the highest coefficient measured, and exactly the same coefficient as for respiration in this plant, which in itself is a striking point, seeing how different the processes are. (See fig. 5, Assim.)

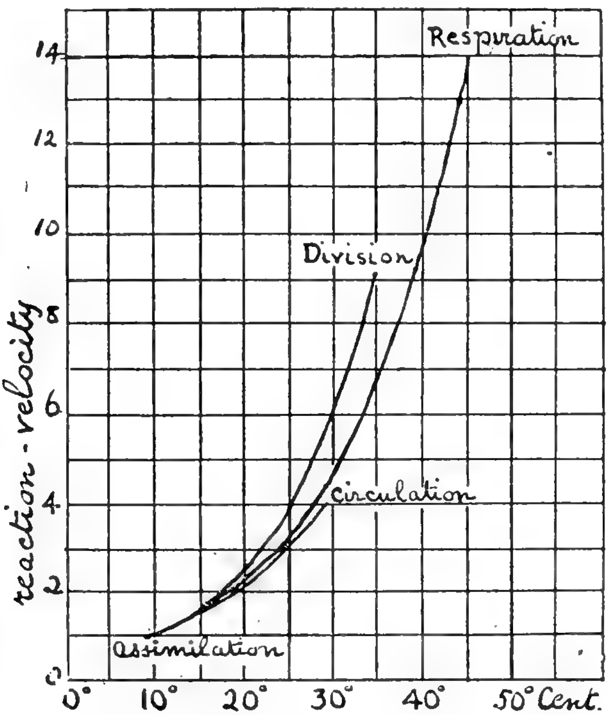

FIG. 5.

The decrease of the coefficient with successive rises is a state of things which is quite general among non-vital reactions. A critical consideration of the matter leads one to the conclusion, however, that this failure to keep up the temperature acceleration is really due to secondary causes, as is also the appearance of an optimum at about 38° C. Some of these causes have been discussed by me elsewhere,[2] and I hope to bring a new aspect of the matter before the Section in a separate communication. The conclusion formerly come to was that probably in its initial stages assimilation at these very high temperatures started at the full value indicated by a theoretically constant coefficient, but that the protoplasm was unable to keep up the velocity, and the rate declined. It must be borne in mind here that quite probably no chloroplast since the first appearance of green cells upon the earth had ever been called upon for anything like such a gastronomic effort as these cherry-laurel leaves in question. It is not to be

[1] *Phil. Trans. Roy. Soc.*, Ser. B, vol. cxcvii. 1904.
[2] 'Optima and Limiting Factors,' *Annals of Botany*, vol xix April 1905.

wondered that their capacities speedily declined at such a banquet, and that the velocity-reaction of anabolic synthesis traces a falling curve in spite of the keeping up of all the factors concerned, to wit, temperature, illumination, and supply of CO_2. This decline is not permanent, but after a period of darkening the power of assimilation returns. Physical-chemical parallels can easily be found among cases where the accumulation of the products of a reaction delays the apparent velocity of the reaction, but this complicated case may be left for further research.

In relation to assimilation, then, we must say that owing to secondary causes the case is not so clear over the whole range of temperature as that of respiration, but that at medium temperatures we have exactly the same relation between reaction-velocity and temperature.

We may consider now some data upon the combined net result of anabolic and katabolic processes. Such total effects are seen in their clearest form among unicellular saprophytic organisms for which we have a few data. Mlle. Maltaux and Professor Massart[1] have published a very interesting study of the rate of division of the colourless flagellate *Chilomonas paramæcium* and of the agents which they say stimulate its cell-division, in particular alcohol and heat.

They observed under the microscope the time that the actual process of division into two took at different temperatures. From 29 minutes at 15° C. the time diminished to 12 minutes at 25° C., and further to 5 minutes at 35° C. The velocities of the procedure at the three temperatures 10° C. apart will therefore be in the ratio of 1 : 2·4 : 5·76, which gives a factor of 2·4 for each rise of 10° C. (See fig. 5, Division.)

Now we are told by the investigators that at 35° C. Chilomonas is on the point of succumbing to the heat, so that the division rate increases right up to the death point, with no sign of an optimum effect. Below 14° C. no observations are recorded.

Here, then, we have throughout the whole range exactly the same primary temperature relation exhibited by the protoplasmic procedure that we should expect for a chemical reaction in a test-tube.

This division phase is only a part of the life-cycle of the flagellate, and between division it swims about anabolising the food material of the medium and growing to its full size ready for the next division. One wishes at once to know what is the effect of the temperature upon the length of the life-cycle. Is the whole rate of metabolism quickened in the same way as the particular section concerned with actual division? Of course a motile flagellate cannot be followed and its life-cycle directly timed, but the information was obtained by estimating carefully what percentage of individuals was in a state of actual division at each temperature. It was found that always 4 per cent. were dividing, whatever the temperature. This proves that the whole life-cycle is shortened in exactly the same proportion as the process of division at each temperature, and that it is just twenty-five times as long. Therefore the life-cycle is 125 mins. at 35° C. and 725 mins. at 15° C., so that here, again, we have the physical-chemical relation with a factor of 2·4 for each rise of 10° C.

In this paper of Maltaux and Massart these relations are not considered as the manifestation of physical-chemical principles, but are regarded as reactions to stimuli; and the paper contains a number of experiments upon the effect of sudden changes of temperature upon the occurrence of division. As far as one can make out from inspection of the scattered literature, it does seem established that sudden changes of temperature act as stimuli in the strict sense of the word. In many investigations one finds it stated that a quick change of temperature produced a certain reaction which a slow change of temperature failed to evoke. Usually all the phenomena are treated in terms of stimulation, and the absence of reaction with slow change of temperature is regarded as secondary. Were it not for the specific stimulatory effects of quick change, which are not difficult to comprehend as a phenomenon *sui generis*, I hardly think so general a tacit acquiescence would have been extended by botanists to the view that all enduring

[1] Maltaux and Massart, *Recueil de l'Institut botanique Bruxelles*, tome vi. 1906.

changes of velocity of metabolism brought about by lasting changes of temperature are stimulatory in nature.

No determination of the rate of development of bacteria through a very wide range of temperature seems to have been made. There are various incidental experiments which indicate values about 2 for the coefficient of increase of metabolism for a rise of 10° C.

I am not acquainted with any data for the growth-rate of whole flowering plants at different temperatures. Of course the case of growth most usually measured in the laboratory, namely, where one part of a plant extends at the expense of the reserves stored in another part and there is a decrease, not an increase, of total dry weight, is not the type of growth we have to deal with. Even for simple elongation of a shoot at different temperatures we have but few data. Those of Koppen (1870) generally quoted are wildly irregular, and in many cases it is clear that the growth-extension of complex structures is a process which proceeds by spasms rather than smoothly.

The rate of movement of circulating protoplasm increases rapidly with temperature, but Velten's numbers do not give an obvious logarithmic curve. If we confine our attention to the values for 29° C. and 9° C. we do find, however, that the velocity increases about twofold for each rise of 10° C. being 10 mm. at 9° C. and 40 mm. at 29° C.

Taken altogether these various data clearly support the hypothesis that temperature accelerates vital processes in the same way as it does non-vital chemical reactions, that is, logarithmically by an approximately constant factor for each rise of 10° C.; and, further, it accelerates them to the same extent; that is, that the factor in question has values clustering about 2–3.[1]

To make these similarities more significant I ought to point out that no other properties of matter are accelerated to anything like this extent by rise of temperature. Most reactions increase in velocity by no less than 10 per cent. per degree rise of temperature; a most marked effect, and yet there is no generally accepted explanation of this almost universal phenomenon. By the kinetic theory of gases each rise of a degree in temperature increases the movements of the gas-molecules, so that the number of collisions between them is greater, but only about $\frac{1}{6}$ per cent. greater. With rise in temperature, too, the viscosity of a solution diminishes, so that there is less resistance to internal changes; but this only to the extent of 2 per cent. per degree. The degree of ionisation also increases, but only extremely little, so that no change of known physical properties will explain the phenomenon. Various hypotheses which need not detain us have been put forward.

Unexplained though it may be, yet the quantitative treatment of the subject is clear enough and, I think, as cogent in the living organism as in the test-tube. If so, we may consider ourselves now justified in separating off from the realm of stimulation yet a third class of causal connection, namely, that between temperature and the general intensity of vital processes.

Conclusion.

In this attempt to assert the inevitableness of the action of physical-chemical principles in the cell, I have not ventured upon even the rudiments of mathematical form, which would be required for a more precise inquiry. Bio-chemistry is indeed becoming added to the ever-increasing number of branches of knowledge of which Lord Bacon wrote: 'Many parts of nature can neither be invented with sufficient subtilty, nor demonstrated with sufficient perspicuity, nor accommodated unto use with sufficient dexterity, without the aid and intervening of the mathematics.'

In this sketch which I have had the honour of outlining before you I have

[1] It has been proposed to use the size of the temperature coefficient to settle whether a process like the conduction of an impulse along a nerve is a chemical or a physical process. See Keith Lucas, *Journal of Physiology*, vol. xxxvii. June 1908, p. 112.

critically considered but few points. I have rather endeavoured to distribute imperfect data in the perspective in which they appear from the point of view of one who seeks to simplify phenomena by extending the principles of chemical mechanics as far as possible into the domain of vital metabolism. Much critical quantitative work has yet to be done before the whole becomes an intelligible picture.

To me it seems impossible to avoid regarding the fundamental processes of anabolism, katabolism, and growth as slow chemical reactions catalytically accelerated by protoplasm and inevitably accelerated by temperature. This soon follows if we once admit that the atoms and molecules concerned possess the same essential properties during their brief sojourn in the living nexus as they do before and after.

Perhaps the more real question is rather as to the importance and significance of this point of view. Protoplasmic activity might be something so much *per se*, and the other factors of the nature of stimuli might be superposed so thickly upon that substratum which should be dominated by simple principles of chemical mechanics that for practical purposes the operations of the latter would be so overlaid and masked as to be negligible. A survey of this field, however, seems to show that this is not so, and that the broad action of the law of mass and the acceleration of reaction-velocity by temperature are obviously responsible for wide ranges of phenomena.

Now the conception at the bottom of these principles is that of reaction-velocity, and the conclusion of the whole matter is that the physiologist must frankly take over from physical chemistry this fundamental conception.[1] Under definite conditions of supply of material and temperature there is a definite reaction-velocity for a given protoplasm, and the main factors that alter the rate of metabolism, viz., heat, nutrition, and traces of impurities are exactly the factors which affect the velocity of reactions *in vitro*.

Working on this basis we no longer need the vague unquantitative terminology of stimulation for the most fundamental of the observed 'responses' to external conditions. Three sets of phenomena we have observed which, though usually treated in the category of stimulation, draw a clearer interpretation from the conception of reaction-velocity. These were: (1) the relation of development to the absence or deficit of single essential food constituents; (2) the occasional striking effect of minute traces of added foreign substances upon the whole rate of growth and metabolism; and (3) the general doubling of the activity of vital processes by a rise of 10° C.

The next higher stratum of principles should be the complications introduced by limiting factors which interrupt the extent of the manifestations of these principles and by various correlations, as, for example, that by which the reaction-velocity of one catabolic process might withdraw the supply of material needed for full activity of another different process. To this sort of relation may be attributed that phenomenon so characteristic of the more complex vital processes and quite unknown in the inorganic world, namely, the optimum.

Finally, superposed upon all this comes the first category of phenomena that we are content still to regard as stimulatory. From the point of view of metabolism and reaction-velocity many of these appear very trivial, though their biological importance may be immense. Think how little the tropistic curvatures of stems and roots affect our quantitative survey; yet a little rearrangement of the distribution of growth on the two sides of an organ may make the difference between success and failure, between life and death.

From our present point of view vision does not extend to the misty concep-

[1] No general treatment of the physiology of plants has yet been attempted in terms of reaction-velocity. Czapek, however, in the introduction to his stupendous *Biochemie der Pflanzen*, vol. i. 1905, does draw attention to the conception of 'reaction-velocity' and refer to the standard literature on this subject and on catalysis, though direct application is not made to the plant. Cohen (*Physical Chemistry for Physicians and Biologists*, English edition, 1903) considers in detail some biological applications of the acceleration of reactions by temperature.

tions of stimulation upon our horizon. We may therefore postpone speculation upon the mechanical principles governing them and await the time when by scientific operations we shall have reduced to law and order the intervening region, which we may entitle the chemical substratum of life. This done we may venture to pitch our laboratory a march nearer to the phenomena of protoplasmic irritability and make direct attack upon this dominating conception, the first formidable bulwark of vital territory.

The following Papers were then read :—

1. *The Influence of Living Cells on the Transpiration Current.* *By* Professor H. H. Dixon, *F.R.S.*

The resistance experienced in the passage of water through wood is considered by some as necessitating the intervention of vital actions in the elevation of the transpiration current in trees. According to Ewart a pressure of 10 atmospheres is required to raise water at the transpiration velocity in an elm-tree 18 m. high. He allows that 3 atm. may be supplied by the traction exerted by the evaporating cells of the leaves, leaving 7 atm. for the living cells to supply, viz., 0·39 atm. per metre of stem. Existing methods should easily reveal the presence of such a force, but up to the present no such force has been detected.

In order to reveal the presence of even a much smaller force of a vital nature, if such exists, the following method was adopted: The rates of transmission from above downwards of two similar branches were simultaneously observed. To maintain both at the same temperature and so avoid differences in viscosity, both were enclosed in the same water-jacket. One branch was then killed by being surrounded with steam, and the rates of transmission again observed as before. The similarity of behaviour of both branches showed that the influence of the living cells on water-transmission is insensible. The experiment gives the same result when the branch is killed with picric acid. In the latter case, in order to subject the two branches to conditions as similar as possible, water was forced through the control while picric acid was forced through the experimental branch.

The fading of the leaves supported by killed branches has also been urged in support of vital theories of the ascent of sap. It is, however, arbitrary to assume that in this case the leaves fade directly owing to the want of water, or that the methods of killing do not bring about changes in the sap and in the water-tracts other than the destruction of the life of the cells. The fading of leaves due to want of water is quite different from the fading of those supported by dead stems. In the latter case the appearances indicate poisoning of the mesophyll-cells, while in branches so killed, even if the tracheæ in the dead region itself escape being clogged, those at higher levels in the stem and in the fading leaves ultimately become plugged with reddish material.

The poisonous effects of water which has passed through a killed branch may be observed by supplying water to the basal leaves of a branch through its distal part, after the latter has been steamed. Although provided with a two-fold supply (viz., from the basal intact organs, and also through the killed upper part), the leaves fade in a manner similar to those on a dead branch.

It will be seen that the experiments described in the paper lend no support to the vital theories of the ascent of sap.

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2. *The Death-rate of Bacteria under the Action of Disinfectants.* *By* Miss Harriette Chick, *D.Sc.*

Disinfection is shown to be a process exhibiting a close analogy with a chemical reaction, the disinfectant representing one reagent and the protoplasm of the bacterium the second. It is shown to be a gradual process without any sudden effects; if the disinfectant employed is sufficiently dilute the reaction velocity of disinfection can be studied by enumerating the surviving bacteria after successive intervals of time.

The process is found to proceed in accordance with the mass law if 'number of surviving bacteria' is substituted for 'concentration of reacting substance.' The number of living bacteria, when enumerated after successive intervals of time, is found to decrease in a logarithmic manner. Although disinfection involves the interaction of two substances—bacteria and disinfectant—the reaction velocity at any period during disinfection is controlled only by the 'concentration' of living bacteria at the time. Disinfection thus recalls a reaction of the 'first degree,' the reason for this being that the concentration of the disinfectant may be regarded as constant throughout, since it is present in so great excess. (An interesting analogy is thus suggested with the case of sugar inversion.)

The experiments upon which the above conclusions are based were made by the author and other workers with both spore-bearing and vegetative types of bacteria, and employing metallic salts, phenol, other coal-tar derivatives, and heat as means of disinfection.

The suggestion is made that the gradual and orderly nature of the disinfection process is due to temporary differences in resistance among the individual bacteria, which themselves may be referred to different rhythmic phases occupied by that constituent of the bacterium concerned in disinfection.

The reaction velocity of disinfection is influenced by temperature in a manner similar to many chemical reactions, and increases logarithmically with rise of temperature. With *B. paratyphosus* and metallic salts the increase was 2–4-fold for a rise in temperature of 10° C. In the case of phenol the temperature coefficient was much higher, between 7 and 8.

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3. *The Death-rate of Cells of Higher Plants in Fatal Conditions.* *By* Miss NORA DARWIN *and* Dr. BLACKMAN, *F.R.S.*

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4. *Colour Changes in Flowers produced by controlling Insolation.* *By* Colonel H. E. RAWSON, *C.B., R.E.*

On March 12, 1905, a wonderful sunrise was observed at sea just after crossing the equator while on a voyage from Southampton to the Cape of Good Hope. Myriads of cirrus threads, as fine as gossamer, suddenly flashed out in the highest levels of the atmosphere, and formed continuous and parallel lines of visible vapour, converging optically to V-points, which were true north and south as the sun rose true east. The V-points did not remain fixed, but moved clockwise, and the whole vault of heaven, with its countless arches of cirrus lines, swung slowly round, as if on a pivot, in the zenith.

The phenomenon did not disappear entirely for some days, and variations in the disposition and movements of the threads in the cirrus level with respect to bands of visible vapour, which formed at certain hours, in the cumulus and stratus levels were noted and measured with instruments.

While endeavouring to explain some of the effects, which were clearly attributable to direct rays from the sun, a crucial experiment suggested itself which could most easily be carried out upon plants.

On arriving at Cape Town some indication of the sun's action in the particular direction suggested was looked for amongst garden plants, and was found in the case of the Kei apple (*Aberia caffra*), which is much used for a border to gravel-walks and flower-beds. This clue was followed up, and experiments were carried out in Pretoria with several different vegetables. These were found to be affected by sun-rays in the way anticipated.

The results obtained were described in a paper entitled 'Sunrise and Growth,' which was read before the South African Association for the Advancement of Science, and appeared in the Report for 1905.

With the information acquired, as to the effect of direct sun-rays upon plants, trials were made in the direction of forcing plants to protect themselves against those direct rays which, in the clear South African atmosphere, at an altitude of 4,550 feet, were proved to be distressing to them. Nasturtiums were selected as most likely to be sensitive to the treatment they were to be exposed to, and trials were commenced with an existing group of growing common nasturtiums, which were already in a suitable aspect, and were shaded by a brick wall at certain hours of the day from all direct rays. Between April 21, 1905, and August 5, 1907, the whole of the group had been changed from the ordinary scarlet and orange varieties into a new mauve variety, with the exception of one plant, whose flowers were changed to the deepest carmine, with velvety-blue markings on two of the petals. A seed from this plant, which was brought from Pretoria and sown under glass at York on March 26, 1908, was changed to the mauve variety by exactly similar treatment at York to that administered in other cases at Pretoria in order to produce the mauve variety from the deep carmine.

The principle which has been followed is to shade off with a perfectly opaque screen all direct rays of the sun for certain intervals of daylight. There has been no other special treatment, and the only fertilisers used have been soot-water and liquid manure. Their judicious use during the correct periods of growth, and their supply in proper strength, are considered of great importance.

At Pretoria the mauve variety proved a veritable mutation, and no known instance occurred of its reverting to the original. Experiment so far goes to show that seeds from it after the second year may be planted in any aspect, and will come true even if sown in such different climates as those of York and Pretoria.

The crimson variety similarly treated in York and in Pretoria gave the same flowers of a bronze old-gold colour in both places, and the seed of this latter variety brought from Pretoria and sown in York gave the same curious colour, in spite of the great difference of altitude between the two localities.

Cuttings of the mauve variety could be grown in any aspect at Pretoria, without any change in the mauve colour of the flowers.

In addition to the mauve and bronze old-gold colours, varieties of rose-salmon and of sallow flesh-colour have been obtained, and no difficulty has been experienced in changing any of the known orange, yellow, or scarlet flowers into these curious colours.

Experiments with dahlias and cosmos indicate that their coloration can be as easily changed as that of nasturtiums by employing similar means.

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5. *The Mechanical and Electrical Response of Plants.* *By* Professor J. C. Bose, *C.I.E., M.A., D.Sc.*

In order to make an accurate study of the effects of external stimulus on the plant, it is necessary to have some means of immediately recording the responsive changes that take place. In making records of motile responses many difficulties are encountered, owing to friction and other causes. The author has overcome these by devising two different types of instrument. Of these the first is the oscillating recorder, in which a very light aluminium recording-lever traces response-curves on a moving surface of smoked glass, which touches the recording-point at intervals of one-fifth of a second. Friction of the recording-point is thus practically eliminated, and as the record consists of successive dots, it also gives the time-relations of the curve. The second method of record employed is that of the optical lever, which enables the movements even of minute leaflets to be self-recorded. A very high magnification may be obtained by its means, and the immediate effects of a given stimulus clearly observed.

Again, by the employment of the method of balance, any variation in the rate of growth under external stimulus finds immediate record.

The author has also shown that a definite electrical change, of responsive character, occurs in all vegetable tissues on excitation. Thus all plants, and all organs of all plants, are shown to be sensitive.

Correspondingly, he has been able also to show that even ordinary plants exhibit the excitatory reaction by motile response.

By the employment of modes of investigation, both mechanical and electrical, he demonstrates the occurrence of two opposite responsive reactions, which are definite under definite conditions. The true excitatory reaction is associated with a negative turgidity-variation, contraction, and galvanometric negativity; while as a result of 'indirect' stimulus, or increase of internal energy, the responsive reaction is of positive turgidity-variation, expansion, and galvanometric positivity.

The author finds, further, that the tonic condition of the tissue is also a factor in determining the character of response. When the tissue is in a state of sub-tonicity on the one hand, or of fatigue on the other, the sign of normal response is apt to become reversed.

By mechanical and electrical tests alike the author is able to demonstrate that there is true transmission of excitation in plants, distinct from the propagation of hydro-mechanical disturbance. The fibro-vascular elements provide preferential channels, through which the wave of true excitation is conducted.

The velocity of transmission of excitation increases with the intensity of stimulus. A moderate rise of temperature is also conducive to the enhancement of this velocity. Cold, fatigue, and the action of anæsthetics, on the other hand, retard or abolish the conducting power.

The character of that effect of stimulus which is transmitted to a distant point depends on the conductivity of the tissue, and also on the intensity of the stimulus. The effect transmitted is of negative sign when the stimulus is strong or long-continued, or the tissue highly conducting. Conversely, it is of positive sign when the stimulus applied is feeble, or the tissue semi-conducting.

The fact that true conduction of excitation takes place in the plant, as in the animal, receives conclusive demonstration from the polar effects of currents on excitation. The author finds that as in the animal, so also in the plant, the normal effect is that the kathode excites at make and the anode at break.

He has also observed the phenomenon of multiple response in vegetable tissues under strong stimulation. A continuity exists in plants as between this multiple and the so-called 'autonomous' response.

The characteristics of rhythmic tissues in the plant are found to be parallel to those of rhythmic tissues in the animal.

The author has also been able to determine with accuracy the death-point of a plant. A mechanical and electrical excitatory spasm is shown to occur at the initiation of death. In the morographic record the critical point is exhibited as a sudden inversion of the curve.

6. *The Mechanism of Mitosis.* *By* W. L. Balls.

7. *A perfectly Fertile Species-hybrid showing Segregation.* *By* Dr. J. P. Lotsy.

8. *The Natural Crossing of the Cotton Plant.* *By* W. L. Balls.

FRIDAY, SEPTEMBER 4.

The following Papers were read :—

1. *Photo-chemical Action in the Test-tube and the Leaf.* *By* Dr. F. F. Blackman, *F.R.S.*

2. *On Increase in Dry Weight as a Measure of Assimilation.* *By* D. Thoday, *B.A.*

The increase in dry weight of unit-area of leaf-surface was first suggested as a measure of the accumulated products of assimilation by Sachs in 1883. He took halves of leaves in the early morning and the other halves after a certain number of hours of insolation, and found the difference in dry weight per square metre.

Comparison with the results obtained by other more exact methods has led to the conclusion that this method tends to give an over-estimate of assimilation. Brown and Escombe (1905) compared increase in dry weight with intake of carbon dioxide simultaneously directly determined, and found the former far in excess of the latter in three experiments out of four. They attributed the discrepancy chiefly to the asymmetry of leaves and to changes in area taking place under experimental conditions, and published a few determinations of the errors introduced in these ways. They also suggested the possibility of a change of capacity for water retention in the colloid constituents of leaves during insolation, presumably as an explanation of the high values usually obtained; and expressed the opinion that Sachs' method is not capable of giving accurate results.

At Dr. Blackman's suggestion I undertook a more detailed investigation of the method, for it is the only method which is available for determining the rate of assimilation in the open air, and if it could be trusted for sufficiently accurate results in its original or a modified form, might prove of service in ecological investigations in the near future. The following are among the most important results:—

Analysis by combustion of portions of material of which the dry weight had been determined showed a fair correspondence between the increase in dry weight and the increase in carbon content, and gave no support to Brown and Escombe's suggestion of a change in capacity for water retention.

Leaf material is often extremely hygroscopic. It should be dried in a current of dry gas and weighed with care to exclude moisture.

The methods of measuring area are or can be made sufficiently accurate.

Errors from lack of symmetry in dry weight per unit area cannot be eliminated. They can only be reduced by avoiding veins and by using a large number of leaves. It is this source of error which will set the limit to the degree of accuracy obtainable by the method.

Change of area by shrinkage during experiment introduces an error the seriousness of which varies according to conditions, and is most liable to vitiate the results of experiments aimed, like those of Sachs, at determining a maximum rate of increase in full sunlight in the open air.

These errors from shrinkage or expansion will require special care in the future use of the method, but present no insuperable difficulty. Floating on water cannot be trusted to eliminate them.

The calculation of the equivalent intake of carbon dioxide from the increase of dry weight can only at present be rough, as too little is known of the composition of the products of assimilation. For more accurate work it may be possible to avoid this difficulty by estimating the carbon content itself.

Sachs' result for the rate of assimilation of detached leaves of *Helianthus annuus,* 16 milligrammes per square decimetre per hour, has been confirmed as substantially correct in this investigation.

Flaccidity, even if but slight, brings about a considerable reduction in the rate of assimilation in leaves of *Helianthus annuus,* and probably in other leaves. Brown and Escombe's results for *Helianthus annuus* are very low, and cannot be taken as a satisfactory indication of what goes on under open-air conditions. Nor can their suggestion be considered universally applicable that the greater results which detached leaves have given when compared with attached leaves are to be explained by differences of stomatal apertures. One of Brown and Morris's results cannot be explained satisfactorily in this way; similarly with several cases among the work of others. When this explanation is valid a further analysis of the conditions is necessary, especially in regard to the relative efficiency of the water-supply.

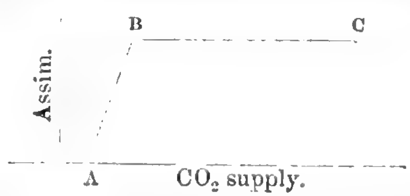
3. *The Factors influencing Photosynthesis in Water Plants.* *By* A. M. Smith, *M.A.*

Description of Apparatus.—The apparatus has as its object the maintenance of a current of water containing dissolved carbon dioxide, so that it passes at a constant rate over a plant enclosed in an oval chamber. This chamber is placed in a copper bath which can be maintained at a desired constant temperature. Through a window in the bath the plant-chamber is illuminated for assimilation experiments by Keith high-pressure incandescent burners, which can be put at varying distances away. Thus the conditions of assimilation (1) amount of CO_2 supply, (2) temperature, (3) light, can all be regulated to any desired intensity. The assimilation or respiration is measured by analysing the CO_2 content (1) of the supply to the plant, (2) of the water which has passed over the plant. This analysis is performed by precipitating the CO_2 in a known volume of the solution as insoluble carbonate by addition of baryta and titrating the excess of baryta by standard hydrochloric acid. The apparatus includes arrangements for collecting and analysing the gas given off during the experiment, so that a complete account is obtained of the CO_2 changes due to the plant.

Experiments.—Blank tests with no plant in the chamber show that a high degree of accuracy can be attained in analysing the stream of water and comparing samples drawn off near its source with samples taken after passing through the whole of the apparatus.

The general course of the earlier experiments made in 1905—and these form the greater bulk of the work—showed the effect on assimilation of a CO_2 supply increasing in amount from that present in ordinary tap-water 0·0007 grms. per 50 cc. to 0·0620 grms. per 50 cc., which represents a solution about two-thirds saturated at 15° C.

Light and temperature being constant the general form of the curve obtained is



Where the part A B represents increase of assimilation with increase of CO_2 supply, while the part B C represents a constant assimilation due to some limiting factor. That this limiting factor is the intensity of the light was proved by increasing this intensity when an increase of assimilation above that represented by B C was obtained. No change was observed on raising the temperature. It was shown by experiments in 1908 with temperatures of 7° C. and 13° C. that in all the earlier experiments the temperature was above the limiting intensity for this amount of assimilation. The later experiments fixed the limiting temperature for this assimilation at 16° C.; and all the temperatures used in the earlier part of the work were higher than this.

That CO_2 supply, light, and temperature were actually limiting under different conditions was shown, not only by the form of the general curve, but in each case by changing the intensity of that factor during the course of a single experiment, when, if the factor was limiting, a corresponding change of assimilation followed.

Besides this demonstration of the conditions under which each factor in turn becomes limiting, other interesting general results are:—

(1) That when CO_2 is limiting, plants with an internal atmosphere (flowering

plants) have an advantage over plants without (mosses) in being able to convert a higher proportion of the CO_2 supplied.

(2) No depressing effect of CO_2 on assimilation could be detected up to a point when the supply was about one-third saturated, corresponding in land plants to an atmosphere containing 33 per cent. CO_2. This supply is from thirty to fifty times as rich in CO_2 as tap-water.

(3) Water-plants are extraordinarily sensitive to external conditions. A night in the laboratory will considerably depress the assimilation, and a week will reduce it to very small dimensions. In order to get results as constant as possible the plant was always, after this sensitiveness had been realised, gathered on the morning of the experiment and in as green and fresh a condition as possible.

Plants unhealthy to the eye, though they assimilate less than normal for the particular light and temperature, yet respond to changes in the limiting factor in the same way as healthy plants do.

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4. *The Carbohydrates of the Snowdrop Leaf and their bearing on the First Sugar of Photosynthesis.* *By* JOHN PARKIN, *M.A.*

The main purpose of this research is an attempt to extend our knowledge regarding the sugars which appear in the leaf as a direct effect of photosynthesis. Few additions have been made to this subject since the publication of Brown and Morris's important results in 1893.[1] From an examination of the sugars in the leaf of *Tropæolum majus* these authors were led to the novel conclusion that sucrose (cane sugar) is the first carbohydrate to arise in photosynthesis, rather than glucose, the hitherto accepted view. This theory was criticised adversely on the grounds that the sucrose might come from the maltose, which is formed from the leaf-starch.

For this investigation a plant has been selected (*Galanthus nivalis*, the snowdrop) which never under ordinary conditions produces starch in its mesophyll; consequently the problem is not complicated by the occurrence of maltose, and hence sucrose, if present, could hardly have this sugar for its source of origin.

Sucrose has been found to occur abundantly in the snowdrop leaf, along with glucose (dextrose) and fructose (levulose). About forty duplicate analyses have already been made of leaves picked at different periods of the spring, at various times of the day and under diverse conditions. The work, as far as it has progressed, allows the following conclusions to be provisionally drawn:—

1. The total quantity of sugars in the leaf is considerable—20 to 30 per cent. of the dry weight as a rule.
2. The amount of sugar in a single leaf increases from above downwards, at the same time the ratio of the sucrose to the hexoses (glucose and fructose) diminishes.
3. The proportion of sucrose to the hexoses decreases as the season advances.
4. At any given period of the spring the percentage of hexose remains fairly constant, no matter what hour out of the twenty-four the leaves may be examined, but that of the sucrose fluctuates greatly. It increases during the day and diminishes during the night. Further leaves detached and insolated contain decidedly more sucrose than their controls.
5. The glucose and fructose appear present in fairly equal proportions; the analyses however as a whole point to a slight preponderance of the latter.
6. Leaves darkened for some days still contain a moderate quantity of sugar. The percentage rapidly falls during the first forty-eight hours of obscurity, and then remains fairly constant. Plants so treated and then re-illuminated show a large increase of sucrose in their leaves, while the amount of hexose undergoes little alteration.

The above results seem more intelligible on the view that in photosynthesis the formation of sucrose precedes that of the two hexoses, rather than that the

[1] 'Chem. and Physiol. of Foliage Leaves,' *Journ. Chem. Soc.*, lxiii. p. 661.

converse takes place. The glucose and fructose can easily arise from the inversion of some of the sucrose. If, however, cane sugar be the first carbohydrate to be formed in the foliage leaf, then the aldehyde theory of photosynthesis becomes less easily imagined. Too little attention appears to have been paid to the possibility of the first sugar of photosynthesis arising in the chloroplast as a product split off from a complex protein aggregate. On this supposition, and granting sucrose as the primary sugar, the still unproven hypothesis of Baeyer, as usually formulated, would scarcely be required.

Further, greater emphasis in the author's opinion should be laid on the importance of sucrose in the higher plants, and its probable rôle as the chief form in which the carbohydrate travels in the tissues. Various investigations point to the plant's capability, when calling upon its non-nitrogenous reserves, of converting these finally into sucrose before utilising them in growth and metabolism generally.

In conclusion the author expressed his indebtedness to Major G. Dixon for much assistance in the analytical part of this research.

5. *The Time Factor in Assimilation.* *By* J. M. F. Drummond, *M.A.*

6. *The Woodlands of Southern England.*[1] *By* A. G. Tansley, *M.A.*

The more or less vague knowledge that we had of the character and distribution of the natural plant communities of the British Isles until the present method of 'primary survey' of vegetation was initiated a few years ago, requires to be made definite and systematic before it can become of scientific value and be made the basis of further research. The present paper was a contribution to that end. Reasons were given for believing that the great majority of existing English woodlands retain enough of their primitive character to permit of their treatment as natural plant communities, though nearly all have been modified by the agency of man to a greater or less degree.

Four main types of natural English woodland were distinguished: The Oak type, the Oak-Birch-Heath type, the Ash type, and the Beech type. The distribution of these, at least in the south-east and in the lowlands generally, apparently depends entirely on edaphic factors, *i.e.*, on the nature of the subsoil, and each type is characterised by a well-marked composition and constitution. The general character of each was described, the principal dominant and commoner subordinate species enumerated, and the mutual relations of the different types discussed.

7. *The Woodlands of Northern England.*[1] *By* C. E. Moss, *D.Sc.*

With slight modifications, the scheme of woodland associations described by Mr. Tansley in his paper on 'The Woodlands of Southern England' is applicable also to the lowlands of northern England. Woods of the Beech type are not found in the north; but the remaining types occur, and are determined by the same factors which apply in the south. These factors are chiefly edaphic ones.

When we come to consider the woods of the higher hills of northern (and of western) England, we find that climatic factors as well as edaphic ones are operative.

Three main types of woodland occur on the Pennines, viz., Upland Oak Woods, Birch Woods, and Ash Woods. The Upland Oak Woods are dominated by *Quercus sessiliflora*. *Q. sessiliflora* Woods occur up to 1,000 feet, and the Birch Woods ascend to 1,500 feet; they form a natural series, and the presence or absence of the Oak (*Q. sessiliflora*) is determined by altitude. *Q. pedunculata*

[1] A joint paper on 'The Natural Woodlands of England' will be published in the *Annals of Botany* during 1909.

is completely absent from the woods of this series; and this fact, and also the different nature of the ground vegetation, distinguishes them from the various types of Lowland Oak Woods. The woods are degenerating, and numerous derivative scrubs occur. The whole of this series falls into the general Oak-Birch-Heath type, and the slight modifications are due to factors correlated with altitude.

The above Oak and Birch series of woods is developed on siliceous soils alone: on the soils of the carboniferous limestones the natural woods belong to the type dominated by the common Ash (*Fraxinus excelsior*). *Quercus sessiliflora* is completely absent from and *Q. pedunculata* is quite local in the Ash Woods of Derbyshire. The Ash Woods have the same altitudinal range as the *Q. sessiliflora* Woods: above 1,000 feet, scrubs derived from pre-existing Ash Woods occur.

Certain intermediate types, such as Oak-Ash Woods and Ash-Birch Woods, were mentioned; and the ground vegetation of the main types was described. The present altitudinal range of the upland woods was compared with that of former times.

MONDAY, SEPTEMBER 7.

Joint Discussion with Section D on the Determination of Sex.
See p. 738.

The following Papers and Reports were then read:—

1. *The Optical Behaviour of the Epidermal Cells of Leaves.* *By* Harold Wager, *F.R.S.*

The observations of Haberlandt[1] and others have shown that the structure of the epidermal cells of the leaves of many plants is such that the rays of light which fall upon them are refracted and brought to a focus either within the epidermal cells or on their basal walls, or in the leaf among the chlorophyll-containing cells. Haberlandt appears to consider that this function is restricted to the cells of the upper epidermis, but although it is in most cases not so marked, it is equally common to the cells of the lower epidermis.

In some leaves the epidermal cells are so regular in outline that they may be compared to the corneal facets of the compound eyes of insects; but usually they are not so regular, and often possess a wavy outline. Nevertheless they are all capable of bringing the rays of light which fall upon them to a more or less definite focus. These lens cells are very widely distributed, and it is very rare to find a plant which does not possess them in some degree, although, as Haberlandt has pointed out, they are more highly developed in shade plants than in those exposed more fully to the light. From some observations which I have recently made, they would also appear to be more highly developed in the shade leaves of some plants than in the leaves of the same plant exposed to the light.

Cells with a very regular outline such as occur in species of *Tradescantia* on both sides of the leaf, the upper epidermal cells of *Ligustrum ovalifolium*, various *Orchidaceæ*, &c., act as very efficient lenses, and not only bring the light to a focus, but are capable of forming clear and distinct images of objects near them. In one case Haberlandt was able to obtain a somewhat indistinct photograph of a microscope stand which was focused upon the basal wall of the cell. More recently I have been able, by appropriate manipulation with the microscope and the use of the Gordon photo-micrographic apparatus, made by Messrs. Beck, to obtain photographs of a variety of objects through cells both

[1] *Lichtsinnesorgane der Laubblätter*, 1905.

of the upper and lower epidermis of leaves of many species of plants. Among these are portraits from life which are clearly recognisable, reproductions of photographs of various kinds, flowers, and other objects direct, and it has even been found possible to photograph trees, houses, and landscapes, and to reproduce simple diagrams in colour on the autochrone plates of Messrs. Lumière.

Haberlandt put forward the hypothesis that the convergence of the light rays causes a differential illumination of the protoplasmic layer on the basal walls of the epidermal cells, and in some way sets up a stimulus which results in the orientation of the leaf into the position in which it can obtain the most suitable illumination. The alternative hypotheses (1) that the orientation of the leaf may be bound up with the absorption of light by the chlorophyll grains, and (2) that the convergence of the light rays may bring about a more efficient illumination of the chlorophyll grains have not, in my opinion, been sufficiently considered. A further possibility that the phenomenon is a purely incidental one, due to the curvature of the cell-walls by turgescence, and not of any utility to the plant, is also deserving of attention.

Observations which have been made upon *Schistostega osmundacea* seem to indicate a clear case of chlorophyll illumination, and in some Selaginellas and Hepaticæ a similar explanation is possible. So also in the case of *Botrydium granulatum*, the spherical form of the cell brings about a total internal reflection of some part of the light rays which fall upon it and causes a very efficient illumination of the chlorophyll grains which form a lining over the whole of the inside of the wall of the cell.

Haberlandt has described cases in which special cells or cell-wall thickenings appear to be developed with a lens function. These appear to be only on the upper epidermis. It is interesting to note that in a species of Mesembryanthemum I have found these special lens cells equally abundant and well developed on both sides of the leaf, and that in *Garrya elliptica* special lens thickenings of the cuticle occur also equally well on both sides. In this last case they are more or less regularly arranged over the whole surface, and appear to be independent of the position of the epidermal cells.

The elongate cells of such leaves as those of Hyacinth and Iris bring the light rays to a focus in the form of an elongate bar of light. The epidermal cells of *Aspidistra lurida* do not cause a convergence, but there is very distinct and transparent nucleus in some of the cells through which an image was photographed. The epidermal cells of the petals of some flowers also form good images through their curved walls, and in the case of a fungus, *Russula emetica*, the spherical cells found in the pileus also bring about a convergence of the light.

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2. *The Contractile Roots of the Aroid* Sauromatum guttatum. *By* Mrs. D. H. Scott, *F.L.S.*

Contractile roots, which have the power of pulling bulbs and tubers down into the ground, have been known for some centuries. Nehemiah Grew, in his work on the anatomy of plants, published in 1682, writes of the descent of 'bulbous roots' being already known to 'botanicks.' He goes on to describe the process in the crocus, &c.; and, in speaking of the cause of the descent, says: 'The immediate visible one are the String-roots, which this kind of trunks frequently put forth, which, descending themselves directly into the ground like so many ropes, lug the trunk after them.'

This mechanism has been worked out in more detail in the present day.

In *Sauromatum guttatum*, a member of the Arum family, the bulb, if placed on an inverted flower-pot, flowers without any water being given it. If then planted on the surface of the soil it throws out leaves. When these begin to wither the tuber gradually disappears from sight, and when dug up in about two months' time was found 6 inches below the surface of the soil. It had thrown out thick, fleshy roots from its upper surface, the tips of which had firmly attached themselves by their root-hairs to pieces of broken tile, bracken, rhizomes, &c.

The roots are found to be contracted to about half their original length. Later on they are cut off by layers of periderm from the tuber, just as a dead leaf becomes detached from its stem.

If one of these tubers is replaced at the surface of the soil it sends out a new set of contractile roots and is again pulled down to its normal depth of about 6 inches.

3. *Evaporation in relation to the Stratification of Marsh Vegetation.* *By* Professor R. H. Yapp, *M.A.*

The evaporating power of the air may be considered as an approximate measure of the pull exerted by the atmosphere on the water contained in leaves and other transpiring organs of plants.

Evaporation readings were taken at different levels in and above the marsh vegetation of Wicken Fen, under varying atmospheric conditions. It was shown that evaporation varies according to the density of the vegetation and the depth of the stratum in which the readings are taken. For example, in the case of a mixed vegetation of marsh plants, about 2 feet in height, the average evaporation in the free air above is about 1·7 times that in the layer immediately below the top of the vegetation, and 6·8 times that in a stratum 18 inches below the surface of the vegetation.

4. *Report on the Registration of Botanical Photographs.*

5. *Report on the Structure of Fossil Plants.*—See Reports, p. 493.

6. *Report on Studies of Marsh Vegetation.*—See Reports, p. 492.

7. *Interim Report on the Sequence of Plant Remains in the Peat Deposits of Teesdale, &c.*—See Reports, p. 493.

8. *Second Interim Report on Research on South African Cycads and on Welwitschia.*—See Reports, p. 494.

9. *A Plant Animal.* *By* Professor F. W. Keeble.

TUESDAY, SEPTEMBER 8.

The following Papers were read:—

1. *The Origin of Dicotyledons.* *By* W. C. Worsdell.

The various existent plant-phyla have a common origin in the remote past. The *similar* structures met with in each group are therefore *analogical*, and not homological in character, and must always represent instances of parallel development along distinct lines.

Embryology and Seedling-structure.

The view developed here is founded on the doctrine of anaphytosis as opposed to the monaxial theory of most observers. The typical plant represents a colony of distinct *individuals* or 'phytons,' budding one out of the other as the 'stem' grows in length (*cf.* formation of stationary colony of aphides). The possibility of propagation by cuttings shows this to be the true interpretation. In the history of such a colony the first *individual* is the *embryo.*

The main question is, does the embryo, or does it not, repeat in its structure that of the group or race to which the 'plant' belongs? Every analogy from the animal kingdom supports the view that it does. Nor is it likely that any adaptive function acquired comparatively recently, however important, can have obscured this primitive structure. If the *stem* had, in the whole ancestry of the plant, always been the dominant organ and the *leaf* a subsidiary lateral one, it would be expected that the plumular axis, and not the cotyledon, would have assumed the rôle of an absorptive organ within the embryo-sac or of an assimilating organ on germination.

It is highly probable that the Angiosperm group, like every other group, roughly recapitulates in its embryonic history the structure of the primeval ancestor from which all groups have sprung. This latter is the primitive Bryophyte. It is the archaic *individual,* showing, in its capsule, seta, and foot, the fundaments and originals of the phyllome, caulome, and root respectively in the vascular plants. The close correspondence in development of the three or four main parts between the embryo of an Angiosperm and that of a Liverwort, like *Jungermannia biscuspidata,* proves that the two are precisely homologous structures.

The facts of embryogeny in vascular plants are entirely opposed to, and inconsistent with, the ordinary teaching that a plant consists of a single shoot on which the leaves are borne as lateral appendages. This teaching is due to the misleading ideas which arise as a result of the study of the later phases in the ontogenetic development of the 'plant,' the importance of which has always been too greatly insisted on. On the other hand, these embryological data are in harmony with the sporogonial theory and the doctrine of anaphytosis. The first one or two foliar organs begin to appear long before the axis: and the subsequent development clearly shows how the leaves are the dominant organs and the axis entirely subsidiary. The primary division of the embryo into an upper and a lower set of quadrants shows that the former represents an organ of closed and limited growth, viz., a foliar organ, and not a leaf-bearing axis of unlimited and indefinite growth. This is due to the fact that each successive leaf is primitively terminal to a segment of the axis, which would result in the leaf being large as compared with the axis on which it is borne.

Eventually the axis asserted itself precociously, and the leaves became pushed over into a lateral position. Both conditions, the primary and the inauguration of the secondary, occur in the embryonic history of Bryophytes (*Jungermannia* and Moss), Ferns (*Ceratopteris* and *Polypodium*), and Angiosperms (Monocotyledons and Dicotyledons).

Inasmuch as in all these groups the first one or two leaves precede the stem during the course of development of the various organs out of the homogeneous thallus structure, it follows that in the primitive vascular plant, including the primitive Angiosperm, there was in the first place a single leaf, terminal to the stem, which by dichotomy gave rise to two leaves.

Hence Monocotyledons must have preceded Dicotyledons; for if the embryo of the latter group does not represent in its history a repetition of the phases of development of the ancestor, it must represent a case of extreme reduction, which is an absurd supposition for such a highly advanced group as Dicotyledons. The monocotyledonous embryo is therefore the primitive sporogonium-like type, and the dicotyledonous type has been derived from it, just as the dicotyledonous embryo of *Selaginella* must have been derived by dichotomy of the single cotyledon of *Lycopodium.*

Modern Monocotyledons show no sign of having been reduced from Dicotyledons. The embryo of the Palm is precisely the same as that of any other typical Monocotyledon. Palms are, of course, very far from being reduced, and the same may be said of any other Monocotyledons. The primitive Angiosperm must have had *alternate* leaf-arrangement, especially if it were derived from a form analogous to the Ferns. Hence if the dicotyledonous embryo repeats the phylogeny of groups, the two opposed cotyledons cannot be primary, but must be derived by dichotomy of a single cotyledon; they cannot be derived by approximation of two alternating leaves, for there is no stem in existence upon which they could alternate at the time when they first arise. Reduction is out of the question in such an advanced group as Dicotyledons; moreover, there is no embryonic type, characteristic of a group, from which such a supposedly reduced dicotyledonous embryo could have been derived. That the dicotyledonous condition is not primary, but that the two cotyledons really represent a single-dichotomised member is shown by the fact that in plants with alternate leaves the two opposed cotyledons are immediately followed by a single leaf about equal in size to the two cotyledons together; the single cotyledon has dichotomised and ensheathed the plumule, this process being best carried out by the two halves becoming opposite and distinct leaves. Cases observed in seedlings of *Cheiranthus*, &c., support this.

If the monocotyledonous condition is derived and reduced, then we ought to find frequent cases of reversion to the dicotyledonous condition; but this is, I believe, unknown, whereas the converse is common, viz., the occurrence of dicotyledonous seedlings with a single cotyledon.

The Pseudo-monocotyledons afford cases where such reversionary processes have become *fixed*. These are true cases of *reduction*. The cotyledon of Monocotyledons is homologous with the foliage-leaf of this group, as is shown by the fact that in Juncaceæ, *Pistia*, and *Sparganium*, the first one to eight foliage-leaves develop in the same way as the cotyledon, *i.e.*, each is terminal to the stem-segment and dominant over it. Reasons are given for thinking that this structure does not necessarily represent a reduction due to the aquatic habit.

If these first few terminal foliage-leaves are homologous with the cotyledon, as is obvious, they must also each be formed by fusion of two opposite leaves, as is supposed to be the case with the terminal cotyledon. Yet it must be conceded that they are similar in every character save position to the remaining (lateral) foliage-leaves of the plant. Hence it is highly improbable that the first and the later formed foliage-leaves should be so different in origin; and it is little short of absurd to suppose that the typical foliage-leaf of a Monocotyledon represents in origin a compound, while that of a Dicotyledon represents a simple organ. Yet this is the logical consequence of the fusion theory as advocated by Miss Sargant.

Anatomy.

The primitive Angiosperm probably possessed a scattered system of vascular bundles in its stem, due to possession of large leaves; these probably grew individually in size by means of secondary thickening. Many Dicotyledons show rudiments of this scattered arrangement in their stems in the form of medullary bundles; where it has vanished from the stem it often persists in the leaf-petioles. This ancestral character could not possibly be exhibited by the seedling, owing to the kind of space-relationships prevailing and absence of large leaves at that stage. The argument from ontogeny is therefore useless in this connection.

The bisymmetry of the vascular structure of the cotyledon of *Anemarrhena*, as pointed out by Miss Sargant, is due to the cotyledon being terminal, not to its being the result of fusion of two organs. The structure of the cotyledon of *Eranthis* is due to the same fact.

Floral Structure.

Pleiomery is the primitive character in the flower, at least as regards the sporophylls. In those orders in which pleiomery obtains—*e.g.*, Palmæ, Alismaceæ, Ranunculaceæ, Magnoliaceæ, Polygonaceæ, &c.—trimery also occurs in one form or another; pentamery is a later character derived by fusion of two trimerous whorls accompanied by elision of a single member.

The correct interpretation of the Monocotyledonous group lies in the assigning to it of an intricate *combination of primitive and reduced characters.*

Monocotyledons and Dicotyledons run into each other at all points, and are intimately allied. They both spring from a common ancestor, and it is the characters of this latter to which the foregoing remarks apply.

2. *A Note on the Morphology of Endosperm.* *By* Professor H. H. W. Pearson, *Sc.D.*

The origin of the Welwitschia endosperm from the fusion of potentially sexual nuclei was briefly described.

Such an endosperm is morphologically distinct from the prothallus of the lower gymnosperm. It is proposed to distinguish it by the term 'trophophyte.'

The relations between the trophophyte of Welwitschia and the endosperm of the angiosperm were discussed.

3. *The Primary Wood of* Lepidodendron *and* Stigmaria. *By* Professor F. E. Weiss, *D.Sc.*

The primary wood of *Lepidodendron*, like that of most Lycopodiales, shows a centripetal development, the protoxylem elements being found in definite groups at the periphery of the stele. In some cases, *e.g.*, in *Lepidodendron esnotense*, figured by Renault, and in *L. Pettycurense*, recently described by Kidston, the stele is composed of a solid mass of wood (protostele), while in one form at least, *L. selaginoides*, the woody mass at the centre is interspersed with parenchymatous elements, a condition of things which may well have led on to the typical siphonostele such as is found in *L. Harcourtii.*

As is well known, the typical *Stigmaria*, the underground organ supporting the Lepidodrendron-stem, possesses a siphonostele with centrifugal primary wood, a condition which it is difficult to imagine to be primitive. At the York meeting of the Association, at which I described a *Stigmaria* with centripetal wood, similar in some respects with Renault's *Stigmaria Brardi*, I suggested that the centrifugal wood so typical of Stigmariæ might have been developed by a reduction of the older centrifugal wood and a substitution of the centripetal primary wood, on the analogy of the 'new' and 'old' wood in the Cycadofilices and Cycadales. But while the occurrence of Stigmariæ with centripetal primary wood supports this theory, a recently discovered *Stigmaria* seems to indicate that, in some cases at all events, the normal stigmarian type of primary wood may have been differently formed. In this *Stigmaria*, in which the stele is comparatively small, though it shows a fair amount of secondary wood, the primary wood is centrifugal in its development, but instead of surrounding a well-marked medulla, the central area is filled with a mass of lignified elements resembling the protoxylem and narrow parenchymatous cells. The arrangement is in close agreement with that found in *L. selaginoides*, except that the vascular elements of this central area are long and narrow instead of short and wide. The stele would therefore have to be described as a protostele of mesarch type, and by an increase of the parenchymatous elements and a decrease of the vascular elements it would be readily converted into a typical stigmarian siphonostele. The arrangement of the primary wood in this new *Stigmaria* resembles on an enlarged scale the primary wood of the creeping stem of *Selaginella spinulosa*, or the hypocotyl of *S. Kraussiana*, except for the admixture of parenchymatous elements amongst the protoxylem. It is interesting to note that already, before the discovery of this new specimen, Dr. Scott had drawn attention to the fact that these two

Selaginellas agreed with the Lepidodendraceæ in possessing centrifugal primary wood in the lower, and centripetal wood in their upper portions. The present specimens possessing a solid protostele strengthens this comparison.

4. *On* Bensonites fusiformis, sp. nov., *a Fossil associated with* Stauropteris burntislandica, P. Bertrand, *and on the Sporangia of the latter.*[1] *By* Mrs. D. H. Scott, *F.L.S.*

A description was given of some curious spindle-shaped bodies, first observed by Miss Benson in petrified material from the Lower Carboniferous formation of Burntisland.

They are found in close association with *Stauropteris burntislandica.* The author discussed their nature and inclined to the view that they are glandular structures belonging to the *Stauropteris.*

The sporangia of *S. burntislandica* were also described. One sporangium was found to contain germinating spores.

This, with the two examples already described by Dr. Scott, makes the third appearance of germinating spores amongst this group of plants.

5. *The Structure of* Sigillaria scutellata, *Brongn.* *By* E. A. Newell Arber, *M.A.*, *and* Hugh H. Thomas, *B.A.*

A full account of the structure of stems belonging to the Rhytidolepis section of the Eusigillariæ has not hitherto been given. In 1906, a grant from the British Association enabled us to procure several beautiful specimens from the Lower Coal Measures of Shore-Littleborough, in Lancashire. The characters of the ribs of one of them agree exactly with those of the impressions known as *Sigillaria scutellata*, Brongn.

The characteristic points in its structure are as follows: The stele has a medullary cavity, surrounded by a continuous ring of scalariform tracheides—the primary wood. The outer margin of this ring is crenulated, and the protoxylem elements lie at the apices of the blunt, rounded teeth of the corona. The secondary xylem forms a band of radially arranged, scalariform tracheides.

A well-developed band of phelloderm is found near the surface of the ribs. This is regarded as having arisen on the inner side of a meristematic zone; no definite cambial layer is, however, found.

The ribs are really formed of cortical tissues, and not of fused leaf-bases. They consist largely of phelloderm, and external to this there is a narrow zone of tissue which is probably the primary cortex. The ribbing of the stem in the Eusigillariæ seems entirely independent of the form and arrangement of the leaf-bases.

The presence of a ligule-pit and ligule has been detected for the first time in petrified specimens. The course of the leaf-traces in the cortical tissues exhibits interesting features. In the leaf-bases, the trace contains a double xylem strand, the two xylem groups being widely separated. The structure of the trace is almost identical with the foliar bundle of the leaf described by Scott as *Sigillariopsis sulcata*, which is obviously simply a leaf of a Eusigillarian stem.

The parichnos increases greatly in size as we pass inwards from the exterior of the stem. The two strands further unite, first below, then above the trace, so that at a deep level in the periderm the trace is completely surrounded by a broad zone of this tissue.

[1] Published *in extenso* in *Annals of Botany*, October 1908.

6. *Notes on the Life History of* Hæmatococcus lacustris. *By* M. Wilson, *B.Sc.*

This unicellular alga is characterised by the possession of hæmatochrom in various amounts, as well as the ordinary chlorophyll of the cell. While the motile cells are often largely green, the immotile resting cells are red, and these alone can withstand drying. A culture of resting cells in 0·1 per cent. Knop's solution gave motile cells partly green and partly red, and eventually entirely green motile cells. This culture was killed on drying. In a more dilute solution the motile cells were at first green, but as the food became exhausted successive generations became partially, and at last completely, red. A portion of a green culture added to a large bulk of water produced red cells after some days. With increasing strength, above 0·2 per cent., the cells were motile for a shorter and shorter time, and eventually passed into the non-motile green condition. In a one-per-cent. solution division occurred, but the daughter cells never escaped, and no further development ensued. In solutions above one per cent. no division took place, and the cells remained completely red.

The size of the cells varies with the concentration of the food substance, being greatest in distilled water and becoming less in successively higher strengths of Knop's solution. In other salt solutions, however, size is not proportional to the osmotic pressure, so that it cannot be supposed that the osmotic factor is the only one at work.

Palmella-like masses of cells are produced in all cultures in Knop's solution, from 0·5 per cent. to nearly one per cent., and also in cultivations on damp, porous tiles.

One-per-cent. Knop's solution is about the highest concentration in which the cells will grow. In considerably higher concentrations they die.

Section L.—EDUCATIONAL SCIENCE.

President of the Section.—Professor L. C. Miall, D.Sc., F.R.S.

THURSDAY, SEPTEMBER 3.

The President delivered the following Address:—

Useful Knowledge.

I propose to speak to you about useful knowledge, and you will, I think, admit the importance and the appropriateness of the subject. But you may be surprised that I venture upon so wide a theme. For my part, I maintain that the extent of a subject gives no notion, however vague, of the time required to discuss it. If you have a quarter of an hour and a sheet of paper you may employ them with about equal probability of success in delineating a hand's breadth of greensward, or the British Isles, or the whole world. Bossuet handled universal history from his own point of view in a volume of no more than six hundred octavo pages, and Buffon [1] remarks, quite truly, that every subject, no matter how vast, can be treated in a single discourse. You will observe with satisfaction that I deny myself the commonest and most plausible excuse for an unduly prolonged address; that, I mean, which pleads the magnitude of the subject.

I do not wish to exaggerate the importance of useful knowledge. It is not everything, nor yet the highest thing in education. There are things which we rarely mention in a British Association section, and which are perhaps best left undiscussed, except where there is entire sympathy between speaker and hearer; some of these stand above useful knowledge of every kind. But the fact that useful knowledge occupies nearly all the school-time shows its practical importance, and disposes us to welcome any means of making it more effective.

Book-learning.[2]

The knowledge of books may be an excellent form of useful knowledge; it may also, when it strives merely to record and remember, be unproductive and stupefying. Let me give you an example, by no means an unfavourable one, of the book-learning which becomes sterile for lack of method and aim. My example

[1] *Discours à l'Académie.*

[2] In the preparation of this Address I have been much embarrassed by the inexactness of the terms used to denote different studies. Some, such as science, literature, &c., include both process and product, which is as if we had but one name for weaving and cloth. The accepted names of the divisions of knowledge are neither exhaustive nor mutually exclusive; they are not so much logical terms as names of occupations, each of which might well occupy one man's time. We acquiesce in such anomalies because we feel the need of brief and comprehensive expressions, and find that bad definitions are not so intolerable as cumbrous and unfamiliar terms.

shall be the elder Pliny, Pliny the naturalist, who lost his life in an eruption of Vesuvius, and whose many virtues were piously described by his nephew, Pliny the younger. The elder Pliny wrote a voluminous Natural History, and left behind him 160 books of unused extracts. His appetite for reading was insatiable. Reading filled all the hours which could be spared from public duties or snatched from sleep. Once, when a friend interrupted the reader to correct a mispronunciation, Pliny asked, 'Did you not understand?' 'Yes.' 'Then why did you interrupt? You have made us lose ten lines.' The Natural History compiled during years of such reading is wholly uncritical; any testimony is good enough for the most improbable story. We look in vain for interpretation, combination, or inference. The facts are indeed rudely sorted, usually according to subjects, but sometimes alphabetically. The chief use of Pliny's Natural History has been to promote the fabrication of more books of the same kind.

Pliny, with his unlimited appetite for knowledge and his very limited power of using it, might seem to have been taken as a pattern by scholars. Like him, they have amassed knowledge in heaps. It has been the ambition of many scholars to read everything that was worth reading, and to fill great volumes with the imperfectly digested fragments.

In the ages of learning, the schoolmaster too became a pedant. His chief duty he supposed to consist in furnishing his boys with knowledge which they might some day want. If it were not that Nature has endowed schoolboys with a healthy power of resistance, their memories might have come to resemble the houses of those who believe that whenever they throw a thing away they are sure to want it again—houses in which room after room is so packed with antiquated lumber as to be uninhabitable.

The Renaissance called up men who made a vigorous protest against unused learning. Rabelais put into grotesque Latin his opinion that the most learned scholars may be far from the wisest of men.[1] Montaigne said over again in pointed phrases what common-sense people had been saying for ages, that he who knows most is not always he who knows best; that undigested food does not nourish; that memory-knowledge is not properly knowledge at all.[2] Erasmus wondered at the practical ignorance of the scholars of his own days—'Incredibile quam nihil intelligat litteratorum vulgus.' Locke refused the name of knowledge to book-learning; real knowledge, he held, was mental vision In the educated man he valued virtue, wisdom, and breeding (manners), ranking them in this order; learning came last of all.[3]

Happily for us, a great deal that we once knew and might foolishly wish to keep quickly fades from the memory. I picture to myself a stream gliding past, and bearing along a miscellany of facts any of which may possibly be useful at some future time. Now and then we stretch out a hand and grasp something which takes our fancy. In nine cases out of ten we drop it immediately. Only a small fraction of the knowledge which enters the mind of an inquisitive person is kept for so long as a month.

What we remember so greatly exceeds what we can use that we need not deeply regret the loss that is always going on. When people explain to us how much valuable substance is wasted by want of care in selecting and preparing our food, I reflect that all of us consume twice or thrice as much food as we can do any good with, and then I am consoled. It is not nearly so necessary to know more things as to know them better, to know what to do with them.

No doubt we often find it necessary to recall a multitude of small facts, in order, it may be, to elicit a general conclusion or to produce a telling argument. But is it wise to prepare years in advance by storing all the facts in the memory? I cannot think so. The study of the bodies of animals teaches us that muscle and

[1] 'Magis magnos clericos non sunt magis magnos sapientes' (*Frère Jean des Entommeures* in *Gargantua*, i. 39).

[2] *Essais*, i. xxv.

[3] Rabelais, Montaigne, and Locke have been collated by Quick in his edition of the *Thoughts concerning Education.*

nerve, which are easily fatigued and require an abundant blood-supply, are never employed in Nature where bone or tendon will serve. Exercise of the memory involves nervous strain, and after an early age a considerable nervous strain. It is more economical and more business-like to employ mechanical contrivances rather than brain-tissue for such purposes, to leave the vast mass of useful facts in grammars, dictionaries, and text-books, and to collect those for which we have a present use in the notebook or the card-index. There is another appliance which the serious student finds almost as useful as the notebook or the card-index—I mean the waste-paper basket.

The history of learning warns us that it is not good to lay up in our memories a great store of knowledge whose use lies far in the future. Apply to knowledge what moralists tell us about money. It is only the money that you may expect to put to use within a reasonable time that does you any good, and the same holds true of knowledge. Unused knowledge, like unused money, becomes corrupt. Uncritical, ill-mastered knowledge is at its best a knowledge of useful things, which, as Hazlitt points out,[1] is not to be confounded with useful knowledge.

If I felt it necessary to show that all book-learning is not futile, I might dwell upon the great subjects of languages and history. But you will gladly allow me to pass on to branches of useful knowledge with which I am more familiar.

Science.

It is the function of science to produce verifiable knowledge. Science achieved her earliest successes by investigating the simplest properties of tangible things—number, form, uniform motion. Here she learned how to combine the knowledge of many concrete facts into general statements, which (to the confusion of thought) we call scientific *laws*. Science applies her general statements to new cases, using facts to make general statements, and general statements to discover or verify facts, so that a considerable part of scientific knowledge is in perpetual use. Science is no longer content with the study of simple properties and tangible things. She will consider facts of every kind as soon as she can find the time. There is no hope of withdrawing from scientific treatment any kind of experience which the human senses or the operations of the human mind furnish; to be safe from the inroads of science you must betake yourself to some study which does not meddle with facts.

Generalisation involves incessant reference of effects to their causes. Facts can only be ill-classified and superficially generalised so long as the causes of the facts remain uninvestigated. Science of any good kind sets up, therefore, the habit of methodical inquiry and the habit of reasoning—productive reasoning, we might call it, to distinguish it from the reasoning of the schools. The best examples of productive reasoning are to be found in the investigations of science, and especially of those experimental sciences which deal with simple tangible objects, whose properties can be studied one at a time.

The virtues of science are exactness, impartiality, candour. Scientific impartiality means the determination to accept no authority as binding except the assent of all competent persons. Scientific candour means perpetual readiness to revise opinions which are held in respect. Loyalty, except of one kind, loyalty to herself, science has no use for and does not cultivate.

I think it is true, but you can judge as well as I, that during the last four centuries there has been no generator of useful knowledge at all comparable with science.

Spencer's Estimate of the Place of Science in Education.

Herbert Spencer has raised the question: What knowledge is of most worth? He considers knowledge in its bearing on life and health, on the gaining of a livelihood, on citizenship, on artistic production and enjoyment; lastly, as a means of discipline. The answer which he gives under each head is 'Science'; that is his verdict on all the counts. A decision so clear, which is, moreover, powerfully

[1] *Round Table*, 'Classical Education.'

and even eloquently supported, cannot fail to be impressive. It is naturally welcome to those who are devoted to the cause of science, and we can all see that, if accepted, it will simplify many troublesome questions. Will it not guide us in choosing a school staff, in drawing up a curriculum, in fixing the future occupations of our children?

But we must first scrutinise the verdict itself. Let us begin by putting a preliminary question so as to remove all risk of ambiguity. Who or what is to possess the knowledge whose worth is to be estimated? Spencer seems to contend that for everybody and under all possible circumstances science is that knowledge which is most valuable, but this is a conclusion hard to receive. There are persons who are intellectually unfit to acquire the scientific habit of mind, or who follow an occupation incompatible with any but a light and recreative study of science. Suppose that a youth is wholly uninterested in science; or that after fair trial he shows no capacity for it; or that he is eager to become a poet; or that he will inherit a lucrative business in which science plays no part; would not these propensities and circumstances modify our choice? I cannot believe that Spencer was so unpractical as to deny them any weight at all. Is it possible that he was thinking of mankind, of the British nation, or of some other large collection of men; that it is to the nation or the race that science will prove itself of most worth? If this is the right interpretation, we have some ground for blaming Spencer's neglect to mention so important a qualification. Those who admit that the nation requires scientific knowledge beyond knowledge of any other kind are not compelled to maintain that the individual man must give his chief attention to science. A minute division of labour, intellectual as well as manual, is necessary in modern life, and we become every day more dependent upon other people's knowledge. An elementary knowledge of many sciences, such as Spencer valued and himself possessed, steadily becomes less attainable, and less applicable to real business; less attainable, because the standard is always rising; what was a respectable acquaintance with science in the days when Spencer was educating himself would now be thought no better than a smattering; less applicable, because business now requires and commands the science of experts. The instances which used to be quoted half a century ago of workmen who attended a course of chemistry in a mechanics' institute, and straightway suggested improvements in the manufacturing processes upon which they were engaged, have become rare, and will soon disappear altogether. Business demands the very best science that the age can supply, and it can afford to pay high enough to get it. Obviously the best knowledge of any kind can only be possessed by a few.

Spencer seems to expect that every intelligent mother should enjoy a knowledge of human physiology which will be a sufficient practical guide for the rearing of a family, but here, too, I have my doubts. Since the first publication of his essay the requirements of human physiology have risen in a surprising degree. The knowledge that can be got by reading even so admirable a text-book as 'Huxley's Lessons' does not nearly suffice for the practical adviser. On this point I can speak with experience. When I was preparing for biological work I dissected the human body, took out courses in physiology, and walked the hospital. But this tincture of professional knowledge, though better than that which any elementary or secondary school could supply, has never proved applicable, except to the least serious of emergencies. A little knowledge may indeed be dangerous when it is applied to the diagnosis of disease or to sanitary construction.

Those who agree with me that the science which is applicable to industry or to public health is steadily growing harder of attainment will not, I hope, turn this into an argument for restricting the study of science to a few. The elementary science of the school, if good of its kind, is valuable for its effect upon the character and the intelligence; it is necessary for the timely discovery of young people who can be trained to carry on scientific discovery; and it engenders a sympathy with science which is of high importance to the State. If the science of the school does no more than make the phenomena of everyday life a little more comprehensible and a little more interesting, it will fully justify itself.

Spencer would, I feel sure, have admitted that even when science is to be the chief occupation of after-life, it should not occupy more than part of a well-ordered course of school-study. The chemist or physiologist often requires to express his own meaning by speech or writing; it will be highly advantageous that he should express it clearly and vigorously. He must get effective command of at least one foreign language. He ought to know enough mathematics and drawing to make his own calculations and sketches. He ought to have learned how to use books. Spencer does not exclude literature and the fine arts from education, but in his scheme they are not to claim very much. 'As they occupy the leisure part of life, so should they occupy the leisure part of education.'

I do not suppose for a moment that this passage was written with the intention of pouring contempt upon literature, and it is really appropriate to the current fiction which to-day is, and to-morrow is cast into the oven, but what insensibility to the claims of the higher literature it betrays! 'On traite volontiers d'inutile,' says Fontenelle, 'ce qu'on ne sait point; c'est une espèce de vengeance.'[1]

These considerations move me to reject Spencer's verdict. There is not, and cannot be, a scale of usefulness by which everybody's choice can be at once determined. Before deciding what the schoolboy is to study we must inquire what are his aptitudes, inclinations, and opportunities. And the importance of science, which I do not think Spencer has exaggerated, will be fully recognised when every nation and city, every profession and trade, every person and interest, can be guided as often as need arises, not by their own scientific judgment but by the judgment of scientific experts.

Preliminary Scientific Medical Studies.

Everyone agrees, in the abstract, that scientific information, the heap of scientific facts, is a small matter in comparison with scientific method and the scientific spirit. We do not, it is true, give effect to our convictions in practice. The teacher of science still loads the memory with facts; the examiner in science still passes or ploughs according to the quantity of facts that the candidates have got up. It requires an effort to keep hopeful, but we must go on steadily pointing out what we take to be the right way. The reformers of science-teaching are now bent upon such improvements as these: they wish to see a greatly improved synthesis of the student's knowledge, so that the things that he learns in one place and from one teacher should be intimately combined with what he learns in another place and from another teacher. Further, they wish to see a large extension of personal inquiry and personal verification of the fundamental scientific facts. It is thus, we think, that the future man of science will become possessed of a compact and harmonious body of useful knowledge, which may in favourable cases incorporate with itself the experience of after-life, and exhibit the incomparable virtue of healthy natural growth.

I will continue the discussion a little further with reference to the great problem of the scientific education of the medical practitioner, which has occupied the attention of the scientific world during the whole time of my long professorship, and still seems far from permanent settlement. Medicine is at present our one great scientific profession. It brings science into the daily life of every one of us, and employs it for the protection of some of our dearest interests. The scientific basis of medical knowledge should be sound, compact, well-mastered, and, if possible, productive. I will go on to consider what it actually is, forming my opinion upon thirty years of experience in teaching elementary science to medical students.

Let me begin by making a concession to those who think that things are pretty well as they are. Remembering distinctly what the medical student was thirty years ago and more, I find that the first-year's university student of medicine at the present day is in all respects a better man, more serious, more enlightened, more capable. I find too that his preliminary scientific course seems to do him real good. It is far from perfect, but it is a great improvement upon anything

[1] Dr. Duncan's *Life* furnishes proof of the slightness of Spencer's obligations to literature.

that existed in the remote days when I was myself a first-year's medical student. The labours of the last thirty or forty years have not, in my opinion, been thrown away.

Nevertheless the preliminary scientific studies of the medical man are far from being as effective as they ought to be. Much of his time and effort are spent in laying up heaps of knowledge for which he is expected to find a use at some distant day. The items of scientific knowledge still require to be firmly bound together, and indissolubly associated with professional ideas and with professional exigencies. It is only close association with the work of the practitioner that can keep his knowledge alive.

The preliminary scientific course should give practice in the methods of chemistry, physics, and biology. It should prove by definite evidence characteristic scientific truths. Lastly, it should be closely related to medical practice. Looking round for an inquiry which will satisfy these conditions, one inevitably thinks of the teaching of Pasteur, which is now recognised as fundamental in medicine, surgery, and hygiene. Is it possible to give the future medical practitioner a firm grip of that teaching? I think it is. The first part of the preliminary scientific year I should treat as preparatory. It ought to acquaint the student with the methods which chemistry, physics, and biology employ for the establishment or the criticism of scientific statements. Methods of detecting and estimating; of observing small indications; of drawing; of recording results; of putting questions and bending the mind to their solution, should receive particular attention. The multifarious learning of the text-books should be put aside in order that undivided attention may be give to investigation and proof. I would leave it to the teachers concerned to supply the appropriate training, and to certify that it had been got. The latter part of the same year might be concentrated upon the close study of a very few of those agents which set up fermentation and putrefaction and contagion. A simple practical examination would test the reality of the knowledge of ferments actually gained; I can only hope that the examiners would not expect encyclopædic knowledge. This is not the place for the discussion of details.

Technical Education.

Of technical learning I must say but little, and that little must be said with reserve. For my only acquaintance with the subject is indirect, and arises from long connection with a city and university where technical education is prominent. I hope not to express presumptuous opinions on a kind of useful knowledge which I know so superficially.

Technical education may be pursued in at least three ways: (1) We may seek to qualify the pupil for his calling by a thorough training in some science or art, and then, by the application, under the guidance of an expert, of that science or art to a particular industry. The experience of at least two generations seems to show that this method is really effective; it does what it professes to do. (2) The second method aims at no more than supplying information directly applicable to the industry in question. Surely this is the least profitable of the three. The information is not accurately lodged, either in the memory or in the note-books of the students; it soon becomes obsolete in consequence of the advance of knowledge; and it does little to cultivate intelligence or the power of doing. Where intelligence and the power of doing already exist, mere information may be valuable, but the best storehouse of information is the printed book. (3) Lastly, we may aim at nothing more than facility by repetition. Such practical arts as reading, writing, drawing, needlework, and cookery are largely acquired by imitation and constant practice. Skill in these arts is a tool, whose profitable application depends much upon the intelligence and enterprise of the possessor. Independent attempts to meet difficulties, friendly criticism of these attempts, questioning about the causes of failure, are the expedients which a wise and experienced teacher, ever at hand, would employ. Such a teacher is of course rarely to be had, but is now and then found in a sensible mother. Perhaps the best substitute for the sensible mother would be plain, practical lessons on elementary science, such as the Edgeworths, Dawes, and Henslow used to give.

Literature.

Literature differs from most kinds of useful knowledge in having an immediate value. Like beautiful scenery, health, liberty, friendship, and other felicities of life, it is good in itself, apart from the advantages which it brings. Nevertheless, literature is not satisfied with delighting. Like architecture, it aims at utility as well as beauty, and employs its power of delighting to instruct and guide.

The benefits which we receive from literature are comparable with those which we receive from good society. We are expected to enjoy and appreciate; we are not to be for ever asking: 'What have I got that I can carry away?' Literature may be more than good society; it may compare with the intimate talk on grave subjects of a wise and high-minded friend. Unfortunately those whose office it is to introduce us to literature often treat it as if it were only a particular sort of useful knowledge. They occupy our attention so completely with grammar, metre, etymology, and historical allusions that we have no leisure to enjoy and appreciate. Dr. Bain [1] tells us that we need to be indoctrinated in points of style before we begin to read on our own account, and discourages the reading of entire plays of Shakespeare because we come across long passages which yield no marked examples of either grammar or rhetoric.

I have little fear that the scientific age which is now upon us will be permanently hurtful to literature. No new Lucretius, it may be, will write on the Universe, no new Milton on the Creation and the Fall. But contemplative and lyrical poetry will survive all changes in our philosophy. The higher criticism, which is the study of life as well as of letters, will survive too. One literary art, the art of rhetoric, may be weakened and lost when the scientific spirit becomes predominant—that sort of rhetoric, I mean, which may be fitly described as insincere eloquence. Rhetoric seeks above all to persuade, and in a completely scientific age men will only allow themselves to be persuaded by force of reason. Even in our imperfectly scientific age those men gain most by speech who have something important to say, who say no more than they know, and who use all possible plainness.

It will be enough for my present purpose if we can agree that literature has an aim and purpose of its own, and must not be treated simply as a branch of useful knowledge. Literature and science, for instance, are incommensurable.

The Necessity of Choosing.

It is an intellectual luxury to run over the kinds of useful knowledge that we should like to possess. Among them come languages, ancient and modern, some giving access to high literature, some yielding historical or scientific information, some acquainting us with communities or modes of thought very unlike our own. Then come a multitude of sciences, which perhaps show the engineer how to build railway bridges, or tell the navigator how to cross the Atlantic, or help us to improve our health and lengthen our lives. I barely mention history, geography, and innumerable practical arts. We seem to be led into a well-filled treasury, and invited to say what we will have. But one unpleasant condition is laid down; we may choose what we please, but we must pay for it. A new study generally means outlay of money, and always means outlay of time. We soon find ourselves forced to behave like the man whose wife has tempted him into a fine London shop; like him, we begin to ask: 'How much can I afford to spend here?'

Every headmaster and headmistress is occupied with the eternal question how to make room for all the things that are demanded of the school. Theorisers, who have no responsibility for the time-table, insist from time to time upon new additions, and are happy if they can only express their own opinions with an emphasis which satisfies their sense of justice. It is my opinion that far too much has already been conceded to demands which, reasonable when taken separately, are unreasonable when taken together. I have known the time-table of a girls' school overloaded to such a point that in one form chemistry and English literature got

[1] *On Teaching English*, p. 18.

no more than an hour a week between them. The headmistress no doubt hated the arrangement, but had to conform.

I have said that the grounds for introducing each separate subject are often perfectly reasonable. Thus by ancient usage Latin is made a necessary subject in certain schools. Then a claim is put in for Greek as more interesting and equally important. French and German demand admission, and put forward claims which can hardly be overstated. The result is that some boys in secondary schools attempt four languages, and many attempt three. Then we usually find that no foreign language, ancient or modern, is mastered to the point at which it can be used in reading, writing, or conversation. Our wish to be fair and consistent has landed us in an absurdity. The root of the whole difficulty lies in the fact that while there are perhaps fifteen or twenty branches of knowledge eminently fit to be taught in school, no pupil can profitably undertake more than five or six at a time. The man of business who is inveigled into a shop is better able to resist importunity than the schoolmaster. He will say: 'If you insist upon the drawing-room table, you must go without the chest of drawers; if you insist upon the chest of drawers, you must go without the drawing-room table.' I wish that the headmaster or headmistress might find courage and strength to require that every subject admitted to the curriculum should come round frequently, at least for two or three years; as nearly as may be once a day, but we cannot be rigid in these matters.

The sciences taught in school may spoil one another's chances in the same way. Not a few schools are convinced that they must have chemistry and physics because of their industrial importance, hygiene because of its relation to the health of the community, physiology to make the hygiene intelligible. The schoolboy is made to buy more sciences than he can pay for, and his time is gone before he reaps any of the advantages which are so much desired.

Too Much and too Long.

One inevitable result is that the school hours, including the preparation of lessons, are nearly always too long. Another result is that the schoolboy who is willing, but not very clever, is often overworked. I have known many such cases myself, and have also known cases in which excellent results have been attained in a good deal less than the customary time. If we could consent that our pupils should remain ignorant of many useful things, if we could materially shorten the lessons of very young pupils, and if we could bring the home-lessons into much smaller compass, I believe that the education which we offer would really be more valuable.

Natural and Artificial Education.

If we had a pupil put into our hands for solitary instruction, like the Émile of Rousseau, we should find it wise to begin by studying him closely, and three things would particularly require attention—his aptitudes, his inclinations, his opportunities. The first two are self-explanatory, but the word *opportunities* may present some difficulties. It includes, of course, opportunity of learning, but the chief stress is to be laid upon opportunity of exercise in after-life. This is the opportunity which stimulates interest and rewards exertion. Moral character, intellectual character, curiosity, love of knowledge, equipment for practical life, and, so far as I can see, all considerations which ought to govern the choice of a study, come under one or other of the three requisites—aptitude, inclination, opportunity.

In school we have not so much solitary pupils as groups of pupils to consider, and this compels us to accept compromises, which are familiar to every teacher. We have often to study the wants of a school-form as well as the wants of an individual.

Some writers have given to the education which considers first of all aptitude, inclination, opportunity the name of *Natural Education*, while that which makes its choice of studies on abstract or arbitrary grounds, with little reference to the needs of the pupil, they call *Artificial Education.*[1] We may be allowed to revive these terms for the sake of brevity. To me they seem appropriate as well as convenient in practice.

The advocates of natural education have sometimes reached absurdity by pressing the claims of one of the three requisites to the neglect of the rest. Tolstoy would make inclination supreme, even in early education. He exemplifies Quick's remark that writers on the school-course who are not schoolmasters are almost all revolutionary. Others have attended too exclusively to the opportunity of future exercise. The old grammar schools, thinking much of the future wants of the pupils who might wish to enter the Church, often added Hebrew to the compulsory Latin and Greek. Fortification was frequently taught to little boys. When the Berlin Realschule was founded (1747) it offered, among other things, instruction in the rearing of silkworms and the discrimination of ninety kinds of leather.

Nothing, I think, gives us a clearer notion of what natural education can accomplish under favourable circumstances than foreign travel, which is a form of self-education prescribed by grown-up people to themselves. Even the milder forms of compulsion are wanting here; aptitude, inclination, and opportunity are everything. The preparation, the actual journey, and the recollections yield abundance of instruction to those who use them well. For weeks before setting out the traveller will turn over maps and conversation-books, inquire about handy cameras or collecting-boxes, and study the country which he is about to visit with an eagerness which he never felt before. The journey itself, if only it be such a journey as an active mind will frame, cannot but call forth many powers, physical, intellectual, and moral, that are rarely exercised at home. The love of science, the love of languages, the love of scenery, the love of adventure, the love of society, the love of poetry, all get a new stimulus. And the journey, already profitable in anticipation and in execution, is not exhausted when we return home. Our experiences in unfamiliar countries vivify many a page of history and many a scrap of useful knowledge which would have been otherwise languidly remarked or passed by altogether. Some years ago I had occasion to read the travels in the Levant of old Belon, a French naturalist of the sixteenth century. Though I had a purpose in reading them, they made no impression, and after a few months nothing survived but some pages of dry and unprofitable notes. Then I visited the Greek Archipelago myself, and one of the things that I made a point of doing when I came back was to read Belon again. I found it an entirely new book, full of curious and valuable observations. Now I dwelt with keen interest on his account of the various nations which had made settlements in the Archipelago, on the Greek language, on the Cretan customs of wine-drinking, on the fishes and birds, and on a hundred other details which had seemed totally uninteresting before I visited the eastern end of the Mediterranean.

Let us suppose that all is done, not *by* the traveller, but *for* him, that routes are chosen, hotel-bills paid, carriages and boats hired, languages interpreted, information supplied, all without effort on his part. In a few months he will barely remember what places he has seen and what he has passed by. This may remind us that natural education is only kept alive by *doing*.

Of course the grown-up person is not like a child, and there is need of steady and impartial government, of drill, in short, if the child is to take all the pains that are indispensably necessary in school-work. All our teaching cannot be recreative. Does not this show, some of you will say, that your natural education is inadequate, and that a sterner thing, which takes little or no account of inclination, is demanded in school?

I think not. I think that inclination is a power that we ought to employ as often and as far as we can. No doubt it is inadequate; our very definition makes inclination only one of three requisites. The child at school may usefully remind us that the opportunity of future exercise in some cases becomes necessity, and will take no denial. Nevertheless all three should be considered, and that teacher

[1] See, for example, Henry Sidgwick in *Essays on a Liberal Education* (1887).

will prosper best who lets none of them drop out of sight. Do not forget, too, that inclination is the modifiable requisite; we can stimulate, and even create it; we can also fatally discourage it. It is only natural education, I still maintain, which can count upon the energetic co-operation of the child.

On the other hand, if we ignore aptitude, inclination, and opportunity—if we pour out information upon which the pupil does no work, merely because we think it ought to be good for him, then we have a dull, perhaps a sullen, mind to deal with, which neither will nor can learn to good purpose. The example for all time of artificial education is, or lately was, the setting of every boy in every grammar school to learn Latin, if not Latin and Greek.

Those who believe that natural education is at once the most formative and the most productive, that it helps to build up body and mind, that it encourages the acquisition of truly useful knowledge, should attend to one point which often escapes notice. Natural education demands leisure for the pupil. At the present moment the leisure of the pupil has been reduced to a very small amount indeed. We strive for efficiency, for good examination results, for knowledge of useful things. The negligence of the old race of schoolmasters, which winked at monstrous abuses but allowed a certain independent school-life, has been replaced by zeal and conscientiousness, which occupy every hour, and sometimes treat independent occupations as mere idleness. Long rambles, such as were the delight of my boyhood, when we used to go miles in search of a wasp's nest, are in certain modern schools abolished by compulsory games. Some day or other (the reform will not come in my time) we shall recognise that the chief occupation of the young child should be spontaneous natural play.

That interesting book called 'Public Education,' now nearly a hundred years old, in which we find a description of the methods practised by Rowland Hill and his brothers at Hazelwood and Bruce Castle, is inspired by the desire to make education natural and not merely artificial; so is that older and still better book, 'Edgeworth on Practical Education.' There are modern English schools which give fair opportunity for natural education. I pass over some, perhaps many, out of mere ignorance; but I will name two which I happen to know—Bedales School and the Friends' School at Bootham, York, both of which have discovered how to combine natural education with efficiency.

Heuristic Methods.

Dr. Armstrong's heuristic method is well known in this section. He tells us that neither the name nor the thing is altogether new, and the same may be said of nearly every educational expedient. Promising schemes are proposed, tried perhaps on a small scale, and dropped, often for lack of enterprise on the part of the teachers, and years after someone discovers them again. Dr. Armstrong tells us[1] where he got the name, and quotes a passage from Edmund Burke, which clearly describes the method. It is now a good many years since I saw Mr. Heller give several lessons on this plan in elementary schools in London, and was then permanently convinced of the real value of the heuristic method. I only wish that we had a score of such, each worked out as carefully as Dr. Armstrong's model.

The method need not be confined to experimental science, nor to science at all. I have attempted something of the same kind in elementary biology. Why should not teachers of history carry out a little historical research with the help of an upper form? Suppose that the subject chosen was English town and country life in the sixteenth century. Harrison's Description of England, Shakespeare's plays, Walton's Lives, some of the modern books which collect the testimony of foreign visitors during the reigns of Elizabeth and James I., Spenser's View of the state of Ireland, and Hume Brown's Scotland before 1700 are, let us suppose, accessible to the class. Useful materials from these and any other sources might be arranged in a card-index. Co-operation is eminently desirable,

[1] *The Teaching of Scientific Method, &c.*, 1903, p. 235

and a little club of pupils might well make their index in common. Then the materials should be treated in literary form, every detail of literary workmanship receiving attention. I fully expect to be told that this plan has actually been tried in some school or other. The historical researches of the school may give opportunity for the use of foreign languages, for map-drawing, or for the handling of statistical information.

Mr Greening Lamborn's 'School History of Berkshire'[1] is interesting as an investigation carried out by and for the boys of an Oxford school. It will be read in a very different spirit from that with which the condensed school-history of England is received, and will no doubt suggest more work of the same kind. The share of the boys may well grow larger and larger.

The advocates of learning by inquiry and learning by doing will descend even into the nursery. What an opportunity is afforded by toys!—an opportunity that those who purchase all their children's toys throw away. Surely every little girl ought to be encouraged to make plausible dolls out of the rag-bag, every little boy to make his own menagerie, his own boats and whistles and sledges. Even the bought toy gives opportunity for inquiry. Ask any child if he has noticed that the animals of the Noah's Ark are always thicker at one end, usually the hinder end. There is a reason for this, and a curious reason, which the child may be helped to discover.

Mastery of Something.

Let us indulge less than we do the passion of intellectual avarice, if only because avarice blinds us to the relative values of things. The old French anatomist, Méry, said of himself and his colleagues that they were like the rag-pickers of Paris, who knew every street and alley, but had no notion of what went on in the houses. The accumulation of miscellaneous knowledge of useful things, copious, inexact, inapplicable, may, like rag-picking, leave us ignorant of the world in which we live. Let us try to reach the inner life of something, great or small. The truly useful knowledge is mastery. Mastery does not come by listening while somebody explains; it is the reward of effort. Effort, again, is inspired by interest and sense of duty. Interest alone may tire too quickly; sense of duty alone may grow formal and unintelligent. Mastery comes by attending long to a particular thing—by inquiring, by looking hard at things, by handling and doing, by contriving and trying, by forming good habits of work, and especially the habit of distinguishing between the things that signify and those that do not.

It is too much to expect that mastery will often be attained in school. School is but a preparation, not I think for promiscuous learning, but for the business of life. The school will have done its part if in favourable cases it has set a pattern which will afterwards develop itself naturally and harmoniously.

The following Papers were read:—

1. *The Outlook: A Grand Experiment in Education. By* Professor H. E. Armstrong, *F.R.S.*

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2. *Education under a Local Authority. By* R. Blair, *M.A.*, *B.Sc.*

I. The London Council became the Local Education Authority for the Administrative County of London on May 1, 1904. The Council not only succeeded to the powers and duties of the London School Board, but is also required 'to maintain and keep efficient all public elementary schools within the area which are necessary.' Further the Council, which had previously, under the Technical Instruction Acts, been responsible for the supply of technical education, was

[1] Clarendon Press, 1908.

entrusted by the Act of 1903 with powers relating to all branches of higher education, and was commissioned 'to supply or aid the supply of education other than elementary, and to promote the general co-ordination of all forms of education.'

All matters relating to the exercise of their powers under the Education Acts, except the power of raising a rate or borrowing money, stand referred by statute to the Education Committee of the Council, and the Council before exercising any such powers, unless in their opinion the matter is urgent, receive and consider the report of the Education Committee with respect to the matter in question. The Council may delegate to the Education Committee any of their powers under the Education Acts except their power of raising a rate or borrowing money. The Education Committee is composed of fifty members, of whom thirty-eight are members of the Council, and twelve co-opted members (including six women). The powers and duties of the Education Committee are distributed among eleven sub-committees. The Education Committee is assisted by 180 statutory bodies of managers for provided elementary schools, while the statutory bodies of managers of non-provided elementary schools number 367. In the management of its own secondary schools, training colleges, technical institutes, and schools of art, the Education Committee is assisted by advisory or local sub-committees. The Council also appoints representatives to serve upon the governing bodies of all schools and institutions to which it makes grants.

II. Area of the administrative county, 120 square miles; population, 4,795,757. School rolls: *Public elementary*, 734,288; provided, 566,086; non-provided, 165,620. *Public secondary*, 32,010; provided, 3,070; aided, 16,158; non-aided, 12,779. *Technical*, 50,800; provided, 7,700; aided, 38,600; non-aided, 4,500. *Ordinary evening schools*, 121,208. *Training colleges*, 1,363.

In these figures neither the University of London, the Imperial College of Technology, nor the Schools of the University are included, although the Council aids them all.

The Council spends five and a half millions sterling (round figures) on education, 4,500,000*l.* on elementary, and 1,000,000*l.* on higher. The receipts amount to 1,750,000*l.*; the rest of the cost falls on the ratepayer. The education rate is 19*d.* per pound; a penny rate raises about 185,000*l.*

The administrative staff consists of 1,000 officers, including 41 inspectors and 28 organisers; and there are 20,000 teachers engaged in some 3,000 schools or departments of schools of all kinds.

III. The Council purchases sites, designs and erects its own schools, equips the schools with furniture, desks, books, and apparatus; supplies fuel and light; does its own repairs; engages, pays, trains and affords further training to its own teachers.

IV. *Elementary Schools.*—Education is free in all public elementary schools (provided and non-provided). The enforcement of school attendance employs a large body of officers. With relatively few references to the magistrate the average school attendance is maintained at 88·9 per cent. of the average roll.

The subjects of instruction, in addition to those usually found in public elementary schools, include elementary science, nature study, domestic economy, manual training, physical exercises, swimming, and in certain cases modern languages. A strong endeavour is made by means of conferences and consultative committees to secure in the management of the schools the assistance of the expert views of the 20,000 teachers.

Much attention has been given to medical inspection, a comprehensive system having been established before the passing of the Education (Administrative Provisions) Act of 1907.

Voluntary funds provide meals for necessitous children.

Some 2,000 of the ablest of the children in the elementary schools annually receive scholarships, including free education at secondary schools; in the majority of cases the scholarship holders are assisted by maintenance grants. There are further scholarship schemes for trade schools and for higher institutions, including the Universities. For the weakest, medical inspection. For the physically and mentally defective, special schools, with a roll of 9,000; and for those not under control there are industrial and reformatory schools.

Voluntary associations provide play centres, vacation schools, country holidays, and happy evenings for thousands of London elementary school children.

Physical education, including organised games and medical inspection, have received much attention and are going to receive more. Visits to places of educational interest are a feature of the school work. Some of the elementary schools have themselves organised school journeys. The Council has experimented on open-air schools. A small botanical department supplies to the schools 900,000 plants and other Nature-study specimens per month.

There is an annual requirement of 1,100 elementary teachers. These are in the main obtained by means of the 'College List,' a procedure understood to be special to London. Some eighty head-teachers are appointed annually, according to a scheme of promotion which begins with consideration of the claims of every eligible assistant. A scheme for further training brings the practising teachers into direct contact with the University.

V. *Secondary Schools and Training Colleges.*—The Council's policy is to provide or assist in providing secondary education at a moderate fee for those who are able to avail themselves of it, and to offer the advantages of secondary education free of charge to the most promising children from the elementary schools. As previously shown, the secondary schools of London contain 32,010 pupils, 3,070 in the Council's own secondary schools, 16,158 in aided secondary schools, and 12,779 in non-aided secondary schools. These numbers include the students attending the first-grade secondary schools, where the leaving age is approximately nineteen, but they do not include any pupils in attendance at private secondary schools.

The cost of secondary schools, scholarships, the training of teachers, and University education, apart from the administrative staff and loan charges, is estimated at 540,000*l.* for the present financial year. This sum includes 80,000*l.* grant to aided schools, irrespective of scholarships and maintenance of scholarship holders.

The Council has itself established seven training colleges, with accommodation for 1,900 students in training.

VI. *Technical Education.*—The work of polytechnics, technical institutes, schools of art, science, art, and commercial centres, and ordinary evening schools is all being co-ordinated. These institutions, apart from their day work, provide education for 200,000 evening students. The work ranges from repairing the defects of elementary education to education of a University standard, students in some of the polytechnics working as externals or internals for the degree of the University of London.

The cost of the Council's own technical institutes and schools of art was 53,541*l.* in the session 1906–7, while in the same session 87,249*l.* was paid to aided technical institutions, including the twelve polytechnics. The ordinary evening schools cost 135,880*l.*

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3. *Special Schools for the Physically Defective and the Mentally Deficient.* *By* Mrs. E. M. Burgwin.

A report on 'The Scientific Study of the Mental and Physical Conditions of Childhood, with particular reference to Children of Defective Constitution, and with Recommendations as to Education and Training,' was published in 1895, with the result that the Lord President of the Council at that time appointed in 1896 a Departmental Committee to inquire into the existing systems for the education of feeble-minded and defective children 'not idiots or imbeciles.' The outcome of the recommendations of this committee was an Act of Parliament which received the Royal Assent in August 1899, and is known as the Elementary Education (Defective and Epileptic Children) Act, 1899.

This Bill is permissive only; it gave increased grants from the Imperial Exchequer, and enabled the education authority putting the Act into force to retain the children in school until the age of sixteen.

The late London School Board opened its first school for the mentally deficient in July 1892, and for the physically defective in 1901. There are now eighty-four schools, with a roll of 6,006 for the mentally deficient, and twenty-eight schools, with a roll of 2,255, for the physically defective; these latter are brought to school in ambulances in charge of trained nurses. The school hours are from 9.30 A.M. to 3 P.M., with a midday interval of one and a half hours. The premises consist of light and airy class-rooms, with a corridor hall and kitchen. A good dinner is provided at a cost of 2*d.* per head, paid by the parents. The teaching is given by trained and certificated teachers, the morning session devoted to mental work, and the afternoon to art and suitable handicrafts.

The mentally deficient attend from 9.30 to 12 A.M., and from 2 to 4 or 1.30 to 3.30 P.M., according to the recommendation of the managers of the schools.

Pupils are admitted to the schools by the London County Council medical officer, who on examination enters in a book called the 'Family History' the particulars of the child's ailments, whether mental or physical. The teacher keeps the 'class progress' of the pupil in a separate book for each child. The truth concerning the family history is often very difficult to obtain, especially in the case of the mentally deficient. All these schools are in charge of the Special Schools Sub-Committee, consisting of eleven London County Councillors and four co-opted members.

The aim in teaching the physically defective is to train them to become good workers, in spite of their infirmity, and for the mentally deficient to develop intelligence through the motor senses, and so quite three-quarters of their time is devoted to manual and kindred occupations, with the result that many can obtain remunerative work on leaving school. It is generally estimated that here and on the Continent one per cent. need this special instruction. The classes in the special schools consist of boys and girls, but experience shows that the senior boys are better separated from the junior mixed classes, and so they are now being taught in separate schools advanced manual work—*e.g.*, woodwork, boot-making, tailoring, and gardening (where possible). The Royal Commission's Report may give further impetus to this higher training.

The physically defective need expert trade teaching for four years before leaving school, and the lower-grade mentally deficient permanent custodial care in a working colony. Only by decreasing consumption can we reduce the numbers of cripples, and by the segregation of the unfit the numbers of the feebleminded and insane.

FRIDAY, SEPTEMBER 4.

The following Report and Papers were read :—

1. *Report on Studies most suitable for Elementary Schools (with Introductory Statement by Sir Philip Magnus).*—See Reports, p. 495.

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2. *Discussion on Education in relation to Rural Life.*

(i) *Education in relation to Rural Life. By* L. C. MIALL, *D.Sc., F.R.S.*

Special training for the occupations of rural life satisfies the three requisites of natural education, viz., aptitude, inclination, opportunity. (See Presidential Address to the Section, 1908.)

In the near future the practical applications of biology will demand far more serious consideration than they receive to-day. The raising of crops, the management of gardens, the prevention of insect plagues, the food-supply of the sea, are obviously of first-rate importance, and a good supply of trained naturalists competent to advise upon such industries will be found essential to the national welfare. Natural history, which is too often looked upon as no more than an agreeable recreation, is really one of the great and permanent interests of mankind.

The great difficulty is to secure an adequate training for the practical naturalist of the future. It is only thorough knowledge which can satisfy the demands of agriculture and horticulture. First-hand observation, the habit of experiment, and the power to make quantitative determinations will be found in this as in other applied sciences to be indispensably necessary.

Elementary instruction in natural history, even when it is offered to the probable inhabitants of large towns, may profitably lead up to such practical pursuits as horticulture. The natural history will be more real, and intellectually more valuable, if it is directed towards a practical aim.

At present what may be called labour-saving contrivances are far too popular in the classes where biology and Nature-study are taught. Of these labour-saving contrivances pictures and lantern-slides, ready-made preparations (dead, of course), printed descriptions, museum lectures, &c., are much recommended and employed. It may safely be said that the knowledge which will help to develop industries is not to be got by such facile methods.

There are already a few teachers scattered over the British islands who are taking a more promising course and striving to lead their pupils to see, to handle, and to think for themselves. Our hopes for the future rest upon the gradual increase of teachers of this type.

(ii) *School Gardens. By* Miss Lilian J. Clarke, *B.Sc., F.L.S.*

School gardens looked after entirely by the children have been found most useful as a means of education. In connection with Nature-study lessons the following have been proved to be of the utmost value:—

1. *Climbing Plants.*—A convenient arrangement for climbing plants is a screen made of trellis work or wire netting about six feet high, attached to wooden uprights at intervals. It is useful to have these screens even when wall space is available, as children in an outdoor lesson can stand each side of the screen and draw the various contrivances by means of which plants climb. A good selection shows plants climbing by twining stems, stem tendrils, leaf tendrils, petioles, and hooks.

2. *Pollination Experiments.*—These are especially valuable, as the results of many of these experiments are not known beforehand. The children find out what flowers can be self-pollinated by fixing a muslin frame over the plants or tying up flowers in muslin bags, and thus ascertain what flowers are dependent on visits of insects for the production of fruit.

3. *Fruits especially adapted for dispersal by wind, animals, &c.*—It is well to include in the gardens plants which have interesting fruits as well as those which have interesting flowers. Outdoor lessons can be given on the dispersal of fruits by means of plumes, wings, hooks, &c., and the children can see which plants easily spread.

4. *Experiments in connection with the Food of Plants.*—Experiments can be made by placing stencils of tinfoil on the leaves of plants growing in the garden. By means of these the necessity of light for the formation of starch can be shown in a simple manner, and the children learn how important it is for plants to have plenty of light. Nasturtium and sunflower leaves are useful in these experiments, and the plants are easily grown by children.

5. *Soil Experiments.*—(*a*) Growing plants year after year in the same soil without supplying any manure and noting the effect. (*b*) Inoculating plants, such as peas, with bacteria, and comparing the crops produced from similar plants not inoculated. (*c*) Growing plants in various soils, and noting the effect of the soils on the plants and the different treatments required. It is quite easy to grow plants in chalk, clay, sand, and see the influence of the soil on the life of the plant.

In addition to gardens planned in connection with the Nature-study work the children can own vegetable gardens and learn to grow beans, cabbages, tomatoes, &c., at very slight cost.

A special knowledge of plant life is gained by looking after the various gardens mentioned above, but, as well as this, the children learn incidentally many things which will be of value to them in rural life.

(iii) *The Problem of Rural Education in Irish Primary Schools.* *By the* Right Rev. Dr. Foley, *Bishop of Kildare.*

Agriculture should not be regarded as a subject which can be taught in the primary schools by the ordinary school teachers. All that appears feasible in this connection is that there should be central schools in which pupils, who have gone through the primary school course, would be taught the principles involved in agricultural operations by the county agricultural instructor, or by specially trained teachers under his direction, and working under the supervision of the department of Agricultural and Technical Instruction.

As regards gardening, much could and should be done in the primary schools; and it is satisfactory to know that this was the conclusion unanimously arrived at by a committee consisting of representatives of the National Board of Primary Education and of the Department of Agriculture and Technical Instruction. It was the general feeling of the committee that a good deal could be done by means of suitable object-lessons to familiarise the pupils of the primary schools with natural phenomena, and in this way to prepare their minds for the reception of technical knowledge, should their circumstances put them in the way of obtaining it. The first thing required is power to acquire school plots compulsorily; and it is hoped that the Chief Secretary will assist in gaining this end. Otherwise it will not be possible to introduce the subject of gardening extensively into the schools of Ireland. These gardens would be of the greatest service to the rural schools, not merely from the utilitarian point of view, but also from that of true education. Nothing is better calculated to impart interest and actuality to the object-lessons in the schools.

The question of the training of the teachers also needs consideration. Although Ireland is an agricultural country, a school teacher is rarely met who has any taste for gardening or agriculture. Hence the work will have to be begun *de novo*, and the foundations laid in the training colleges.

(iv) *Rural Education.* *By* George Fletcher.

It seems desirable to define as clearly as may be the nature of the reform desired. It should be plainly understood that there is no desire to displace or supersede the fundamentals of a general education. Indeed, it is less a question of the introduction of a new subject into the curriculum than the infusion of a new spirit into the system. So long have we continued to run in the academic groove that primary education seems to have become a thing somewhat remote from the lives of those receiving it; and this want of relation is the more marked in the case of rural schools. The lesson in geography too often deals with a foreign country while the pupil remains ignorant of his immediate neighbourhood. His early steps in art are dogged by the acanthus-leaf—although in this matter we are mending somewhat—while his problems in arithmetic suggest a Stock Exchange rather than the countryside.

It may be admitted that the sole test of the fitness of any subject in the curriculum is its value as an educational agent; but it needs to be recognised that the commonest things in one's everyday environment may be made to serve an educational end. If every school in town and country possessed and utilised freedom to make its surroundings a means of education the problem would be in a fair way to solution. This, however, involves the introduction of the spirit to which reference has been made, and this can only come through the teacher. The problem then, as in so many cases, resolves itself into the question of the training of teachers. In connection with this, it is desirable to urge the value of carefully arranged summer courses of instruction as a means of affording supplementary training of the type in view, for teachers.

MONDAY, SEPTEMBER 7.

1. *Discussion on Education in Ireland.*

(i) *Character and Educational Efficiency. By* T. P. Gill.

This author, while dealing with the general question in the title, referred also to the situation in Ireland, which is now at a moment of great significance for education. A new university system is about to be organised, and the country is being called on to take stock of her whole educational equipment and to consider the end to which she wishes it to conduce. The situation is thus one of general as well as particular interest. What results does the country intend her educational system to produce? By what means does she propose that the results are to be produced? How does she propose to assure herself that she is getting these results? In other words, what is to be the aim, the method, and the test of the educational activity of the nation? It is one of the most practical tasks of the hour in Ireland to consider these questions, and the answers to them should be known and understood by the teachers in every school—from the kindergarten to the university—and, if possible, by every parent.

In connection with the aim of a national system of education it is desirable to examine what is meant by educational efficiency. Efficiency must be considered (1) from the individual and (2) from the social and national point of view. It must be all-round efficiency, physical, mental, and moral—aspects closely related yet distinct in themselves. It is the business of education to develop all three. Again, efficiency is the fitting of the individual (*a*) to pursue efficiently his calling in life, his trade or profession, and (*b*) to be a good man and a good citizen. The professional, the bread-and-butter efficiency is necessary; and not only is it necessary to aim at it in connection with professional or technical education, but from an early stage in general education it is essential that the pupil should be made to think of what is to be his calling in life, and how he is best to prepare himself for it. This object of education, however, must be pursued in such a way as not to eclipse the higher end of producing the good man and the good citizen. On the contrary, it must be realised that the practical efficiency itself is impaired in proportion as the higher end is neglected or lost sight of. National and individual efficiency in every country has suffered from this error. So has national and individual happiness. Ireland must study to avoid this error.

In connection with methods and tests, the suitability of certain methods and tests to produce the results aimed at must be considered. The influence of the test on the method is sometimes so great that it is impossible to separate them. For instance, the fact that a written examination was imposed by law as the sole test has fatally governed the whole character of the Irish intermediate system for nearly two generations. Tests and methods must vary with the things being dealt with. Physical, mental, and moral things cannot be tested in the same way. The subject, the circumstances, and the end in view must always be borne in mind in devising a test or a method. Moreover, in a test, in considering any one part, we must provisionally examine the whole—see if all the parts are there and if the proportions are right. In other words, the time-table, the very vital question of the disposal of the pupil's time, must be taken into account. In a test we cannot look at the individual pupil alone, we cannot judge the pupil apart from the system and the teacher.

Educational tests may be considered under the three aspects, physical, mental, and moral. (1) Physical: in connection with the general bodily development of the pupil, and the effects of bodily health and occupation upon intellectual efficiency and moral strength; in connection with manual training; and in connection with the question in its broadest sense of discipline, order, and method. (2) Mental: the aim of producing a logically disciplined mind. The end of testing here is to see that the observing and reasoning faculty is being rightly trained; that cram is avoided; that observing, thinking, and correlating power is being developed. (3) Moral: the test here should aim at ascertaining whether the teachers have the right outlook and influence; whether the pupil is being really led on to know, admire, and love the right things; to understand his duties, private and public; to select true aims in life; to develop a noble individuality. The importance, in relation to his moral strength and general efficiency, of making the pupil from an early stage think about his trade, profession, or career in life, and of thus giving a personal and purpose-like character to his education.

How are these aims being followed or hindered in the Irish educational system at the present time, and how far is it practicable, by improvements in the methods of testing or other means, to get them followed more effectively? How far is the work of the system in its different branches, primary, intermediate, technical, agricultural, university, susceptible of development in these directions under existing machinery?

(ii) *The Correlation of Primary, Secondary, and University Education in Ireland. By* Professor BENJAMIN MOORE, *M.A., D.Sc.*

One of the greatest evils in the systems of education in Ireland is the lack of co-ordination which everywhere exists. Instead of the three systems forming one interdependent and harmonious whole, each is worked on a separate and entirely independent plan, so arranged as to prevent one system giving assistance or support to the others.

The Board of National Education, which controls the national schools, has entire jurisdiction over the primary system, and in the past has neither sought nor obtained the assistance of the Universities in the training of primary teachers or the supervision of work and examination.

The Intermediate Board, by means of the funds at its disposal, has attained a similar autocratic and bureaucratic control over almost all the secondary or intermediate schools of the country. This Intermediate Board is not in organic relationship with either the National School system on the one hand or the Universities on the other, and has disastrously isolated the whole secondary educational system of Ireland.

The Universities have in the past taken no share in moulding and guiding either the primary or the secondary education of the country, but have confined themselves to training students for entrance to one of the so-called learned professions. The whole nation has suffered from this narrow conception of the educational work of a university; and also the Universities themselves have suffered, even in that portion of work they have been attempting, from the defective preparation of their students at entrance.

The present time when happily two new and modernly equipped universities are coming into existence in Ireland, appears a suitable moment for considering how these defects may best be removed.

It may almost be laid down as an axiom that, unless the new Universities exercise a potent influence on the whole educational system from primary or national schools upwards, they will fail in carrying out their true functions, and of accomplishing the great revival in education which the Irish people have a right to expect, and do expect, from them. The fundamental changes which, it is urged, are necessary in order to bring the three systems into accord and proper co-ordination may be briefly summarised as follows:—

Primary or National Education.—The most essential change here is that the training of the teachers should be placed largely under the control of the Universities, or of a body on which the Universities are strongly represented. The teacher in the primary school is the most important teacher in the country, for he teaches the most preponderating class of the population, and that from which organically all other classes arise. He does not require the special training of the university professor or of the secondary school teacher, but he does require as perfect a training as can possibly be given to him, and on lines peculiarly adapted to his work. It is fundamentally important that this training should be given to the primary teachers by the best intellects the country can afford, and at the highest teaching centre in the country. There should hence, in every modern university, be a Faculty of Education for the training of teachers ranking in honour and standing with the older Faculties of Arts and Science. By intimate contact and fellowship with other university students the primary school teacher will gain appreciation of what true education is, and will, further, find a liberality of thought and development which can never be attained in a purely technical training college. The existing training colleges for teachers can be utilised for supplying the technical portion of the instruction, but should form an integral part of one or other of the Universities.

The nature of the instruction to be given in the national schools, the text-books to be employed, and the nature of revision of work and examination of the primary schools could also be best carried out under the control and influence of the Universities, and the present system might readily be modified to this end with the aid of the present *personnel.* These are the more important changes required in primary education in Ireland; the provision of means whereby children of talent and genius could be assisted to a secondary education is easy of arrangement.

Secondary Education.—The chief thing required here is a liberal control by the Universities, acting in accord with the teachers of the secondary schools. Nothing can be conceived more fatal to the secondary education of any country than having all its schools cast in one mould and of one pattern.

This is the great evil that the intermediate system has brought about in the secondary schools of Ireland. Instead of the liberal freedom which ought to exist in the higher schools, and the power of the teachers to select books and portions of subjects, to develop their own style of imparting knowledge, and of arranging their pupils and disposing of their time according to their abilities and mental trends, there exists the hidebound system of Intermediate Education and the attempt to turn one boy out machine-made exactly like another. Why should the same books be read and the same syllabuses followed in every secondary school in Ireland, whether the teacher has sympathy and enthusiasm for them or whether he detests them? What fire and love of learning can any teacher raise in his boys under such a prison system?

Instead of this let each university within its own sphere of influence recognise secondary schools. Let each school so recognised draw up its own system of work, with the approval and, if necessary, with the assistance of the university authorities, and then let the university act as an external authority in sympathy with the teachers, examining the work done and testing the pupils conjointly with the teachers. The work of the university in relation to the examining of the secondary schools would to a considerable extent be that of the external examiner in the university, the teacher himself acting as internal examiner to see that ample justice was done to the pupil. The final examination of the secondary school would then naturally become the matriculation examination of the university, and the best system would have been arrived at for making this entrance examination what it really ought to be, viz., a guarantee that the matriculant had been so educated that he could with profit proceed to the work of the university.

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2. *Discussion on Training in Teaching.*

(i) *By* Miss C. P. Tremain.

During recent years public interest in educational matters has greatly increased. There is now a tendency to make the provision of the means of education a national, county, or municipal charge, instead of relying on private initiative.

Logically the first step towards improvement in education would be to direct attention to the better professional training of teachers. But school buildings, equipment, codes and curricula, examinations, and systems of scholarships have received far more attention, and the necessity for teachers being specially prepared for their work on intelligent, rational, and thoughtful lines has only lately been realised. Primary school teachers, both men and women, secondary school women teachers, and teachers of special technical subjects form the main body of 'trained' teachers, but even of these a large majority are still untrained. Only a very small proportion of men actively engaged in secondary school teaching, or in directing and inspecting primary and secondary school work hold a teachers' diploma.

The training of teachers has three distinct stages:—

(i) *General Education* in school, college, or university, where the methods of teaching employed have an important, if indirect, influence on future teachers.

(ii) *Professional Training* in training college or department, where the course should include instruction in the theory and practice of education and in school hygiene. The course should be largely determined by the previous general education of the student rather than by his future work; it should be *intensive* rather than extensive as regards time; it is best pursued alone, not as in most primary training colleges along with the general education. The short post-graduate training for intending secondary school teachers seems to give better results than the longer course for intending primary school teachers who are pursuing degree and training courses together.

The purpose in studying the theory of education is to induce a scientific habit of mind in approaching educational questions. Practice in education, which includes the preparation and presentation of lessons by the student, the hearing and reporting on lessons given by others, aims at developing and increasing skill in teaching. The aim of training is not to produce finished and perfect teachers, but rather 'aspiring' and intelligent ones who will be able to adapt themselves to, and learn from

(iii) the *Experience Stage of Training*, in which the student passes into the responsible class-room teacher. This has often been the sole training of successful teachers, but the increasing complexity of life, the urgent need for clear ideals on the part of experts to whom democratic educational bodies look for guidance, as well as the needs of the taught, imperatively demand that future teachers shall regard their work from a professional standpoint. Those who so regard their work will not feel that finality is reached when a teaching diploma has been obtained, nor even when their pupils obtain brilliant examination results.

Theory and practice should correct and supplement each other. This may be attained through the work of students in demonstration schools and classes, and still more by the active participation in school teaching of all members of the training college staff. The teaching should be under the most natural conditions possible, and therefore series of lessons in the ordinary course are to be preferred to criticism and the so-called 'Model' lessons.

Some problems in training which press for solution are—

(*a*) *How to adjust the claims of liberal and professional education*—cf. German and American normal colleges.—The special difficulties in primary school teaching, which have caused a premium to be placed on the pupil teacher system (*e.g.*, unwieldy classes) are gradually disappearing, and many county council schemes show a better way than this for preparing future teachers. Secondary schools are displacing pupil teacher centres and less actual practice in teaching is required of a student before he enters a training college.

(*β*) *How to obtain adequate school practice for those who have had no experience as Pupil Teachers or Student Teachers.*—A demonstration school *plus* classes in schools of different scope and management would seem to afford the best practice. There are special difficulties due to local and other conditions in obtaining adequate practice. Schools are sometimes afraid of admitting graduates who teach under supervision to classes which are readily entrusted to untrained teachers fresh from college.

The work of supervising school practice must be individual, hence training to be efficient must necessarily be expensive. The trainer of teachers in addition to good school experience and progressive knowledge of educational principles needs sympathetic insight in dealing with students.

(γ) *How efficiently to test practical work in teaching.*—Here there has been a great advance from the examination 'show' lesson of earlier days. But it would appear desirable to withhold the full certificate of ability to teach until the young teacher has shown, after experience as a responsible teacher under suitable conditions, his powers as teacher and governor. The executive powers of an individual cannot be tested in the same way as his receptive and reflective powers.

A special difficulty in training at present is that more has to be attempted in the time than can be done efficiently. The secondary school, which is recognised as taking part in the work of training teachers, would render valuable assistance by directing more attention to the subjects which are necessary to every teacher (*e.g.*, the mother-tongue, drawing, clear enunciation, physical culture, &c.).

(ii) *By* Charles MacGregor.

No system of training will ever produce finished teachers; but every system should send forth students with some knowledge of the principles and methods of teaching, and with so much skill in practice as will bridge the gap between experience and inexperience, and serve to lessen the difficulties of that first period of responsible work which is often so profitless to the pupils and painful to the teacher. The students should go forth knowing what has been thought and done educationally in the past, knowing the best that is being thought and done in the present, aware that education is in process of evolution, and full of the desire to contribute to its advance.

1. Sound knowledge is the first essential for teaching of the right kind, and any satisfactory system must be based on a sound general education, or must provide for that. The ordinary school subjects of English, science, mathematics, history, and geography should be re-studied with more maturity of mind, on a higher intellectual plane, and in a more philosophical manner than is possible in a secondary or preparatory school. Concentration of effort should also be aimed at, and the subjects not spread over the whole course as in the Écoles Normales, and in some of the German Seminars and of our own colleges.

2. The students must know not only the material they are to work with, but also the material they are to work upon. They must go through a serious course of psychology, not introspective psychology only, but experimental psychology, and above all child-study. With the study of the mind must proceed the study of the body, and this also must be thoroughly practical, under a competent medical officer. It might include a little anthropometry. A third part of this division should include a short course in ethics, helping the students to the better consideration of the problems of moral education. All this work—psychology, hygiene, and ethics—must possess a vital connection with the students' work in the schools.

3. To the knowledge of the materials students are to use, and the knowledge of the material they are to work on, must be added knowledge of the methods by which these are to be connected and skill in their use. This involves (*a*) history and science of education; (*b*) study of particular methods of teaching school subjects; and (*c*) practice in teaching. Needless to say these three must be correlated in the closest possible fashion. Detachment is disastrous.

(*a*) The history must be brought up to date, and include the work of Parker and Dewey as well as that of Herbart or Rousseau. There should certainly be also a course of lectures on educational systems of other countries, and at least an introduction given to the valuable stores of material in the Board of Education Reports, (*b*) In connection with the study of methods there should be a special school at the Centre, where students may see methods and experiments which they are not likely to see in the ordinary schools. (It is a misfortune that our City schools are not used to some extent for experimental purposes. Some blind experimentation goes on, but little conscious experiment towards a definite issue, and no systematic examination and comparison of results. Joint-committees of head-masters, school boards, training authorities, and of the local inspectorate could do valuable work in this direction.) Each student should be accustomed to the idea of experiment in education, and each also should have to prepare a thesis requiring observational, if not experimental, work.

(*c*) An effective system of training, besides providing for such school-work as will give reality to the studies already mentioned, must allow for an adequate amount of practice in teaching. A student may have an excellent knowledge of methods and yet make a poor use of them.

The period of training for non-university students should be three years, and for university students four. The following is an outline of a suitable arrangement of the professional work for the non-university students.

First Year.—Psychology, experimental psychology and child-study = 100 hours; hygiene = 40 hours; ethics = 20 to 30 hours; two hours per week in the schools, chiefly for observational and experimental work correlated with these subjects.

Second Year.—History and science of education = 100 hours; methods, criticism, and demonstration lessons at the Centre = 60 hours; attendance at schools two hours per week during the winter and four during the summer = 80 hours. At the beginning of the summer should be given out the subject for a thesis, to be handed in at the end of the following winter.

Third Year.—About six hours per week of teaching practice, and at least a fortnight's continuous teaching = 150 to 200 hours; work on thesis and oral on same; special study for kindergarten, housewifery, or rural courses = 200 hours.

During the last two years great advance has been made in Scotland in the provisions for the training of teachers. The country is divided into four provinces with Centres at the four University towns. The gathering of students into these Centres where they can have the best educational facilities has been rendered possible by the grant of use of the public schools for practice purposes, one of the most valuable features of the new *régime*. There are courses of training for elementary and for secondary school teachers, as well as for teachers of special subjects (art, &c.). For the last two classes the period of training is one year; for the first class, two years if they are not graduating and three if they are.

The two-year course is, in practice, a fairly crowded one of 1,800 hours, one-third of which are given up to professional work—education, psychology, hygiene, logic, ethics, methods, and teaching; the other two-thirds are for 'culture-subjects'—science, mathematics, &c. The regulations, however, permit of the omission of any subject of general education from the curriculum. Of the time for professional work, about 250 hours are allowed for the study of methods and practice in teaching. This period is devoted to lectures and discussions on methods, to demonstration and criticism lessons, and to properly supervised practice in the schools. It will be seen that the provisions go a considerable way towards meeting the requirements set forth above.

TUESDAY, SEPTEMBER 8.

The following Reports and Papers were read:—

1. *Report on the Curricula of Secondary Schools.*—See Reports, p. 526.

2. *Discussion on (a) Note-taking and Reports on Work; (b) Clear Speaking and Reading Aloud.*

3. *Discussion on Types of Education and their relative Values.*

(i) *Acquirement in Education. By* Dr. G. ARCHDALL REID.

Some parts of our bodies—the muscles of our limbs, for example—do not grow after birth unless they are used. Other parts—hair, teeth, and ears, for example—develop fully if only they receive sufficient nourishment. All that is developed under the sole stimulus of nutriment is termed inborn by biologists; all that is added under the stimulus of use is termed acquired. In this sense most of the bulk of the human body is due to acquirement. Mind offers an exact parallel to body. Some mental parts, the instincts, for example, develop in us without the aid of experience, which is the term we use when speaking of the mind. But everything we learn is acquired.

The power or faculty by means of which we learn is termed memory. Memory, the faculty not its contents, is of two kinds, conscious and unconscious. The conscious memory stores all experiences that can be recalled to mind, the things we have seen, sounds we have heard, and so on. The function of the unconscious memory is every whit as important. Thus ability to walk or read is due to thousands of experiences stored and concentrated in our unconscious memories.

Intelligence and reason are not innate faculties. We learn them just as surely as we learn to walk or read. They are acquired dexterities in thinking. They depend on memory. Intelligence is that faculty by means of which we consciously adapt means to ends. But we cannot *consciously* adapt means to ends unless we have learned to do so. The caterpillar is not intelligent when he builds his cocoon; for he appeals only to that blind impulse which we term instinct, and which is the very antithesis of intelligence. The man who builds a house is intelligent because he utilises experience. Unlike the adult man, the new-born baby is not intelligent, for he has no experience to which he can appeal. He has only great capacity to learn to become intelligent. Reason is merely glorified intelligence. We have reason, unlike the lower animals, only because our memories are vaster, and because we can learn to be very dextrous in using their contents.

When we send a child to school, we design that he shall learn, not merely knowledge more abstruse than that which he can pick up, like a savage, from the ordinary experiences of life; we intend, also, that he shall acquire right habits of thought. These right habits are acquired mental dexterities. Just as some children can acquire more knowledge and acquire it more quickly than others, so some can learn greater dexterity in thinking, and learn it more quickly than others; but one and all, the quick and the slow, the clever and the stupid, must learn it by means of the memory. An idiot or imbecile is simply a person with a defective memory. He cannot learn knowledge, or he cannot learn to use it, or both.

If we wish to create great skill in thinking, we must create it, as we create great knowledge, by continuing to train our pupils to the latest stage of development over which we have control. Formerly little children were taught nothing but knowledge; now we have invented the kindergarten and the object-lesson. Even the mental training of older boys and girls is improved. But the training of university and college students remains much as it was a hundred years ago. They are still crammed with facts and little more than facts.

The best educational subjects are those which at the same time supply useful knowledge and exercise the thinking faculty. What is useful knowledge? Obviously one condition of its usefulness is that it shall be remembered. The things that we remember are either very impressive things or those which link up with our subsequent experiences, so that we are frequently reminded of them

Much that school or college teach—for example, the kind of zoology and botany taught to medical students—does not link up with the experiences of the subsequent career, and therefore is forgotten as soon as may be, and consequently is useless.

There is a persistent and growing demand for the substitution of scientific for classical study. Unfortunately all that is meant in many instances by scientific teaching is mere science teaching—the mere cramming of pupils with scientific facts without regard to the likelihood of their being remembered, and without care being taken that they are used as materials of thought. It is possible, however, to choose scientific data which link up with the experiences of subsequent life, because they give a deeper and clearer meaning to them; because they help to unify the world the mind creates, and therefore furnish ideal materials for acquiring intellectual dexterity. Only after scientific subjects are scientifically taught shall we be able to demonstrate to the world that the teaching of science is, as it actually is, the best means of creating intelligence.

(ii) *Influence of Mental Values of Types of Education.* *By* Professor E. P. Culverwell, *F.T.C.D.*

While the application of psychology to the practice of education has doubtless been of great service, there is a dangerous tendency not only to investigate but to *decide* questions of curriculum and method on purely psychological grounds. The chief object of this paper is to show that this claim is invalid, and that even our limited knowledge of physiology can give us help in criticising psychological arguments.

The psychological discussion of a question may be as exhaustive as possible, and yet may omit the determining factor; for psychology can never be a science complete in itself. This follows from the fact that changes in mental states may be due to physiological changes which have no mental counterpart—*e.g.*, the whole mental outlook may be changed by a dreamless sleep.

Whether mental conditions are wholly determined when the physiological conditions are given is unknown; yet the following assumptions may be generally accepted:—

1. There is no mental change without a corresponding passage of energy from one region of the brain to another.
2. To every difference in mental action there corresponds a difference in the mode of this passage of energy.
3. Whenever a mental state is revived there is some revival of the corresponding passage of energy. In particular we may assume that if the whole mental state is vividly revived, then the original nervous action is closely repeated; if the revival is but faint or partial, then the corresponding nervous disturbance or oscillation is faint or partial compared with the original one.

These assumptions can be applied to a destructive criticism of the psychological argument against the theory of formal education. It follows from them that there is a marked physiological difference between what we commonly speak of as superficial thought on the one hand and deep thinking on the other, and that experience alone can exonerate the method of interest from the charge of producing superficial rather than deep thinking.

For consider the difference between concrete and abstract thought. Concrete thinking, if mere recollection, implies the revival in its natural form of the nerve disturbance which originally passed. It also includes a comparison of two ideas in regard to a common element which is strong in both. This is a less complicated operation than to compare them in regard to an element which is weak in both. In the former case the excitation follows the natural path—what we may describe as the path of least natural resistance. In the latter case, however, the excitation has to be of a very special character: it must be so arranged as not to excite the more vigorous—and therefore, as we should suppose, the more easily excited nervous oscillations—and yet it must excite the less vigorous ones. If the thinking be very abstract—*e.g.*, the deduction of a common principle underlying many sense experiences which were not simultaneously received—then it is evident that the stimulation must be of a very specialised kind. The great majority of mankind is unable to stimulate the brain in this way. Instead of keeping so many different brain oscillations simultaneously excited, the nervous energy flows along the path of least natural resistance, and some vigorous element in one of the many images to be compared excludes the other ideas altogether.

The Herbartian argument against formal education, as well as such psychological and physiological arguments as those of Professor Bagley in his 'Educative Process,' fall to the ground when examined in connection with the physiological point of view.

It is well to observe that the ordinary man has little power of abstract reasoning. With most men the nervous energy follows the path of natural least resistance, except so far as they are trained. Inconsistent ideas lie side by side in our minds; we can only direct the energy along the natural path. In other words, we take things at their face value. If we had more practice in comparing ideas which lie far apart in our minds (the comparison of which has therefore but little immediate interest), we might see far more deeply than we do. Thus we have no *à priori* right to expect that an education which follows the path of interest will be the best for producing the highest kind of organisation of which a given brain is capable. With some brains no doubt it will. With others it may lead to superficiality.

An instance of the excessive tendency to do away with formal reasoning is to be found in the amount of geometrical construction and example now usual before the principles of true demonstration are entered on.

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4. *Discussion on Experimental Studies in Education.*

(i) *Experimental Studies in Education. By* Professor J. A. GREEN, *M.A.*

The grand method of German educational philosophers has held sway long enough to bring the theory of education into some disrepute. The educator is dealing with facts both stubborn and complex. Unless we are to postulate anarchy for one corner of the universe, there are, underlying these facts, uniformities of sequence and co-existence which it is the aim of educational research to lay bare.

Teaching is essentially a synthetic process. Like the farmer, the teacher may be said to prepare his ground, sow his seed, and look for a return. But the scientific farmer recognises varieties of soil and adapts his measures to them. His training embraces the study of agricultural chemistry, though it is a long way from the test-tube and balance to the plough. At the same time, he does not forget that agriculture is finally an affair of the field and of the weather.

Should not education as a subject of University study be approached in a similar way? Abstract investigations of a scientific and quantitative kind should be possible. These would consist in part, at least, of exercises with individual pupils with the object of a more exact determination of the mental processes of children under instruction. The results arrived at would then be applied to the conditions of the school. The two sides of the work are commonly divorced to the detriment of both. The practising school becomes the demonstration ground of an *à priori* philosophy, and the laboratory loses sight of the fact that pupils are something more than ideational types.

The teacher as such is not primarily a researcher, nor should he be. He wants the result of research in a usable form, and the University Department of Education should be organised with a view to provide them. Some examples of what is being done abroad will indicate possibilities for such a department on one side of its work.

'Observation' as the foundation of teaching practice has received much attention. By using pictures, Stern found that what children see depends more on inner factors than upon the pictures themselves. Up to seven, children take in only isolated objects; about eight, they begin to notice action; at ten, time, space, and other abstract relations begin to appeal to them; and, last of all, they notice the characteristic qualities of individual things. Kerschensteiner's researches into the development of children's drawing powers are an interesting confirmation of these results. The accuracy of children's observing powers, the influence of suggestion upon them, their educability, &c., are points of importance at which Binet, Lobsien, Meumann, and others have worked. Meumann comes to a conclusion which reads like a paradox—'From the general notion to the particular application is the true order of mental development, and not *vice versa*.' Waisemann's investigation into the sensory approach to ideas of number shows the difficulties underlying concrete teaching. He finds that the special grouping of dots is a better avenue than varieties of things, the form, colour, &c., of which distract.

Children's associations have been investigated, and much light has been thrown upon the workings of their minds under school influences by Ziehen, Meumann, Winteler, Schuyten, and others.

The memory of pupils at school has been the subject of much inquiry. On the side of acquisition, it is found to grow steadily during school age, reaching its approximate maximum just at the point where elementary school training breaks off (Meumann). The value of the additional year in the higher primary school is thus not a mere time function. The acquisitive power of memory develops more rapidly under formal training than under the ordinary influence of the school (Van Biervliet).

The importance of a fuller knowledge of individual differences in children will hardly be questioned, and various suggestions have been made for the objective determination of relative capacity. Kraepilin's attempt to express a man in figures, as a steam-engine is expressed in horse-power, though objectionable from many points of view, is a bold attempt to sum up the quantitative study of mental phenomena—attention, grasp, productivity, fatigue-resistance, educability, retentiveness, &c. Binet's work upon intelligence approaches the same problem from a different though highly suggestive standpoint.

Laboratories have already been instituted in Antwerp, St. Petersburg, Leipsic, Milan, and Buda Pesth for experimental inquiry into the problems which confront the teacher.

(ii) *Scientific Method in the Study of Education.*[1]
By Professor J. J. Findlay, *M.A.*, *Ph.D.*, *and* P. Sandiford, *M.Sc.*

In the paper presented at York, Mr. Findlay confined his attention to experimental studies in school *teaching*, and indicated the lines on which he and others were at work in Demonstration Schools,[2] associated with Departments of Education or training colleges. The time now seems ripe for a wider review of methods for the improvement of education which, in a broad sense, may be described as 'experimental' or 'scientific': experiments in teaching form only one section of a large field which is being tentatively worked in many parts of the world.

1. A first group consists of investigations which do not directly raise questions of education at all, but are concerned solely with the physical powers of childhood, and their development; they are really questions of physiology and hygiene—a branch of anthropometry. To these may be added inquiries into feeding, clothing, sleep, &c. It must be borne in mind that while such inquiries are invaluable as material for educational proposals, they are not of themselves directly of service,

[1] A sequel to a paper read at the York Meeting of the British Association. Vide *Transactions*, 1906, p. 793.

[2] Some of the results of the work in Manchester, as well as an account of the methods employed, are to be found in *The Demonstration School Record*, No. 1 (The University Press, Manchester, 1908).

and the interpretations put upon them are often wide of the mark; for the school is a social organisation which has to do its work under complex social conditions.

2. Allied to the above may be placed investigations into school appliances, and the physical conditions under which children live while at school. This is a branch of public sanitation, rather than distinctively a matter for pedagogics.

3. The third group is concerned with the organs of sense, eyesight, hearing, &c.; and we are still in regions where the physiologist and the physician are at home, rather than the teacher. Their results need to be handed over for the use of schools, but the methods and processes of research are not a distinctive concern for the teacher.

4. A fourth group carries us forward to experimental psychology, to research in which the methods of the pyschological laboratory are applied to the features of the growing organism as distinguished from the adult.

A large mass of very suggestive research has been undertaken, of which the work on 'Fatigue' may be taken as typical. The most recent results show the grave difficulties encountered in endeavouring to interpret physical conditions in terms of mind (see Ellis and Snipe, 'Amer. Journ. Psychology,' 1903, p. 232).

Experimental psychology, when the subjects of an experiment are children, undoubtedly would appear to have a close bearing upon the problem of the teacher, and a good deal of the work undertaken in Germany under the title of 'Experimentelle Pädagogik' (see Schwarz in 'School Review,' Chicago, January to September 1907) shows that many investigators would desire to see stations for research in genetic psychology established as part of the equipment of Departments of Education.

It would appear, however, as if the methods of the psychological laboratory are too specialised, and too remote from the positive functions of the school, to be introduced as part of the pedagogical equipment of a university. Rather one would say that such a laboratory ought *to be at hand* wherever advanced work in the study of education is set on foot; and the psychologist ought to be asked to pay special attention to genetic studies in view of the practical importance of any results which he may reach. It is certain that if the laboratory can arrive at new conceptions of the mental life of the young, these results will find an immense field for application in the teaching profession.

5. Of an entirely different order are the numberless investigations conducted under the name of Child-study, especially in America by Stanley Hall and Earl Barnes, and more recently in Germany by Kerchensteiner and others. Here the investigator deals with experience, with mental 'content' in ideas and feelings, or output in expression, rather than with mental qualities or faculties. These investigations, when conducted with real scientific ability, have greatly influenced the schools, for the teacher's business is directly concerned with the child's output: the fundamental difficulty felt by the psychologist as to the nature of mind process is largely avoided when attention is confined to achievement.

6. All the above groups are conducted on well-recognised lines of control experiments, with quantitative measurements. But they only bring us to the threshold of the school; experiments which touch directly the business of the teacher encounter several difficulties—(1) they need a long period of time for their completion; (2) disturbing and qualifying factors are always presented, and cannot easily be reckoned with; (3) methods for estimating results have scarcely as yet been seriously considered. Such methods must obviously vary for each branch of instruction or school management. Both in selection of the material of a curriculum, in methods of teaching, and in the corporate life of school a great amount of experimental work is being undertaken, but it can seldom hope to be placed on the same footing as regards exactness such as is attained in the earlier groups. Further, such work can seldom be undertaken without some *à priori* bias of general principles as to the underlying aim and function of the school.

It is, however, in this group that the proper business of a Department of Education centres: and it is here that the scientific attitude is most urgently needed by demonstrators and instructors. Material, Method, Corporate Life—each of these three sections—can be treated from the standpoint of scientific method.

One of the pressing problems for investigation is to consider principles on which results can be tested: here we should refer to a remarkable inquiry conducted in American cities by Dr. Rice.[1] Our English examining bodies collect every year a large mass of material which could be utilised to capital advantage for research, if means were at hand.

8. This leads us to a final group which takes the student outside the school walls: the administration and control of educational institutions. Here we have a field in which the methods of political science offer the model.

This cursory sketch serves to indicate the vast field that lies before the teaching profession when the time comes for the teacher to be trained on lines which demand an approach to scientific method. There are some signs that the Government, which controls so intimately the training of teachers, is beginning to realise its responsibility to take the lead in this work, by affording means to universities and training colleges to make a beginning: the Education Bill of 1906 contained a clause on behalf of Demonstration Schools. But a fully equipped Department of Education in a university would be at least as costly to maintain as a medical school. It may be worth while for this Association to set on foot some means for collecting information as to the extent to which work is being attempted (either in Departments of Education or in schools) of a quality that can make pretensions to be regarded as scientific.

5. *Report on Changes affecting Secondary Education.*—See Reports, p. 525.

[1] Published in *The Forum*, from January 1901 to January 1902.

EVENING DISCOURSES.

FRIDAY, SEPTEMBER 4.

Halley's Comet. *By* Professor H. H. Turner, *D.Sc., F.R.S.*

The British Association is to meet next year at Winnipeg. Before it reassembles on this side of the Atlantic in 1910 we may expect to have seen Halley's Comet, which last appeared in 1835, and is calculated to return to perihelion in April 1910. The comet will not be so striking an object as Donati's in 1858; but it is the most famous of all comets for two reasons:—

(*a*) Its long sequence of appearances at intervals of about seventy-five years, which have now been verified (by Messrs. Cowell and Crommelin, of the Royal Observatory, Greenwich) back to 240 B.C.

(*b*) The circumstances under which it became associated with the name of Halley, who in 1705 first realised its periodic returns and predicted that of 1759.

Halley's discovery of the periodicity followed naturally from the great work of Newton on gravitation, which first suggested the character of the movements of comets. Newton's 'Principia' was presented to the Royal Society in 1686. Only twenty years earlier, in the very first number of the 'Philosophical Transactions,' we find an attempt by a certain Monsieur Auzout to predict the motion of the comet of 1664. And he claims this as a 'design, which never yet was undertaken by any Astronomer; all the World having been hitherto perswaded, that the motions of *Comets* were so irregular, that they could not be reduced to any Laws.' M. Auzout, however, got no further than the suggestion that the orbit lay in a plane; and in a later paper he extends his method to the comet of 1665.

What is not understood is apt to be disquieting and even terrifying, and comets had been in olden times, and were still, at that date, regarded as causing pestilence and war. Milton writes in 'Paradise Lost,' Book II. 708:—

. . . like a comet burn'd
That fires the length of Ophiuchus huge
In th' Arctic sky, and from his horrid hair
Shakes pestilence and war.

'Paradise Lost' was finished in 1665, and these words have been supposed to refer to the very comets of 1664 and 1665 considered by M. Auzout, which were held responsible for the Dutch War and the Great Plague of London. But Milton was by that time blind and did not see these comets. He probably had in his mind, at any rate in addition, the much larger comet of 1618, which he had seen as a boy of ten, and which had a tail 104° long, and was actually in Ophiuchus, as suggested in the passage quoted. The great Thirty Years' War was attributed to this comet (see Evelyn's 'Diary').

In the few centuries elapsed since Milton the world has forgotten its superstitious dread of comets, which are now (*a*) much more familiar and (*b*) much better understood.

(*a*) They are more familiar through the development of the telescope and increase of assiduity in searching for them. Half a dozen are found every year, and it would be difficult to identify their malign influences. Some are found quite by accident, as when Mr. Holmes in 1892 turned his telescope to look at the nebula in Andromeda and found a comet; or when Professor Barnard found the faint trail of a comet on one of his photographic plates. Others spring into view almost suddenly, so bright as to be seen by several observers simultaneously. Others, again, are found by most patient searching. The great majority are never seen by the naked eye, but can readily be photographed. Such photographs show beautiful structure in the tail, which always points away from the sun, as if blown by a current of wind outwards from the sun. It seems probable that the light emitted by the sun acts much as a current of air would, and by its pressure drives away the lighter particles to form the tail.

(*b*) They became better understood from the moment when Newton announced the great law of gravitation. It was at once suggested that comets might move in orbits round the sun under his attraction. The orbits were clearly not circular like those of the planets, but Newton's work pointed to long ellipses or parabolas as alternative forms. Halley, the devoted disciple of Newton, on being appointed Savilian Professor of Geometry at Oxford in 1704 set about the task of computing the orbits of as many comets as had been well enough observed, and in his famous paper, 'Astronomiæ Cometicæ Synopsis,'[1] gives computed elements of twenty-four comets, from 1337 to 1698. This involved almost incredible labour, and is in itself a title to fame. But, as often happens in scientific work, the most important outcome was unexpected. Three of the orbits were so nearly the same as to suggest a recurrence of the same comet. The elements were approximately as follows:—

Date of Comet	Interval	Longitudes of Node	Longitudes of Perihelion	Inclination	Distance
	Y M	°	°	°	
1531, Aug. 24. . . .		49	301	18	0·567
	76 2				
1607, Oct. 16		50	302	17	0·587
	74 11				
1682, Sept. 4		51	302	18	0·583

It will be seen that there are some slight differences; but the point which chiefly arrests attention is the difference in interval between the returns. Halley divined the explanation that this was due to the disturbing action of the planets. It was known that the intervals between successive returns of the planets Jupiter and Saturn were not exactly equal, and he ascribed this to their mutual attractions. How much greater might not such errors be in the case of a comet which moved much more slowly? He saw no difficulty that could not be explained, and confidently predicted the return of the comet in 1758, or thereabouts. In a later edition (not published until 1749) of his paper he reflects with just national pride that, though he could not hope to live to see the return (he was born in 1656 and died at the age of eighty-six in 1742), posterity would remember to credit an Englishman with the prediction. 'Quocirca si secundum predicta nostra redierit iterum circa annum 1758, hoc primum ab homine Anglo inventum fuisse non inficiabitur æqua posteritas.'

It was in every way appropriate that this grand discovery should fall to Halley. He was, as above mentioned, Newton's devoted disciple, and, more than that, it was largely due to Halley that Newton's 'Principia' was ever published. It was Halley who sought from Newton, after failing elsewhere, the answer to the

[1] *Phil. Trans*, vol. xxv., March 1705.

question, 'What curve will a particle describe if attracted to a centre by the force of gravitation?' He journeyed specially to Cambridge to ask this question; and never has a more momentous journey of an Oxford man to Cambridge been taken. Newton was able to reply, to Halley's delight, 'An ellipse.' He had solved the problem some time before, and then tossed it aside as solved—so carelessly that he could not find the solution. But he sent another solution to Halley later, with much other new knowledge, which developed with extraordinary rapidity into the 'Principia.' When this was presented to the Royal Society they had no funds to publish it; but Halley, though then a poor man, had been formerly a rich one, and retained the rich man's contempt for financial difficulties. He published the 'Principia' at his own expense, showing the same enthusiasm which was capable of taking him all over the world as captain of his own ship to try and solve the longitude problem, and later of gluing him to his chair to compute cometary orbits with unprecedented labour. It was a tremendous epoch in scientific history; and the smallest details relating to it are of interest. Fresh light was thrown upon it some years ago by the rediscovery of an autograph letter from Newton to Hooke dated November 28, 1679. Hooke claimed that he had himself been the first to announce the solution of the question above mentioned, put by Halley to Newton, and asserted that Newton had in the first instance supposed that an attracted body would move in a *spiral* to the centre, and that he (Hooke) had first told Newton that the curve would be an *ellipse.* The letter recently discovered and now in the possession of Trinity College, Cambridge, is the actual letter wherein Newton draws a spiral curve; but it also makes it clear that he was at the moment considering a totally different problem, viz., what would be the path *relative to the rotating earth* (not the orbit in space) of a falling body. This most interesting letter therefore bridges a gap in a most important episode.

Halley's Comet returned, as he had predicted, 'about 1758'—really in 1759, a little later than his rough date. The delay was due to the perturbing action of the planets, and had been anticipated by calculation; so that Halley's prediction, in making which such perturbations had been expressly recognised, was the more completely verified. The comet went round once again and reappeared in 1835; and now we are eagerly awaiting the next return in 1910. Calculations of the circumstances of return have meantime been chiefly made by foreign astronomers, but in the last year or two Messrs. Crommelin and Cowell, of the Royal Observatory at Greenwich, have done splendid work of this kind. Mr. Cowell has suggested a method of work which greatly shortens the calculations, and, with the able assistance of Mr. Crommelin, mistakes in other calculations have been rectified, and a prediction made which should be close to the truth. The comet will be brightest in May 1910, but a search will be made for it much earlier; indeed the search was commenced last autumn, though without success. It will be renewed this autumn, when success is more probable, and the comet when found will be followed along its orbit with the greatest interest by many telescopes.

But although England until recently left to others the exact calculation of modern returns, a fine piece of work on the past history of the comet is due to an Englishman, Mr. J. R. Hind. In 1849 he examined old records, especially the Chinese annals, and collected accounts of remarkable comets which could fairly be identified with Halley's.[1]

The following is his list:—

Probable Early Returns of Halley's Comet (Hind).

A.D. 1456	1145	837	530	218
1378	**1066**	760	451	141
1301	989	684	373	66 A.D
1223	912	608	295	12 B.C.

The comet of 1066 is represented on the Bayeux tapestry, and was held

[1] *Monthly Notices R.A.S.*, vol. x. p. 51.

responsible for the conquest of England. Halley, who was delighted that an Englishman should be first to recognise the periodical character of the comet, would no doubt have been deeply interested by this curious association with an important epoch in our history had he been led to suspect it.

The verification of these dates, rendered probable by Hind, has been nobly carried out by the Englishmen above mentioned, Messrs. Cowell and Crommelin. (Mr. Crommelin is an Irishman, but an assembly of the British Association in Dublin takes no note of such details.) Mr. Crommelin wrote to the present ecturer on July 28:—

'We have now carried back Halley's Comet to B.C. 87 (August) with certainty (one revolution earlier than Hind's list), and with fair probability to B.C. 240 (May). Before this observations are completely wanting. Hind is one and a half years too late for his 608 (A.D.) return (it really was 607 March), but all his earlier returns are right up to the beginning of his list (−11 = B.C. 12). We find 1910 April 12·9 for the next passage, but are going over the work again by a new method.'

This date makes the comet at its brightest, to our earthly view, in May 1910. In that month there will be a total eclipse of the sun, visible in Tasmania, and the most glorious view of the comet obtainable at this return will probably be that accorded to those in Tasmania during totality. (Does this signify an extension of the national associations of the comet to our colonies?)

The year 1910 is also the tercentenary of the first use of the telescope by Galileo. We are reminded how much we owe to astronomical work in the three centuries since elapsed. Not merely are we no longer terrified by comets; our whole conception of the magnitude and meaning of the universe has been changed. Much of what we have gained we owe to Halley, who showed that comets were no strange monsters, but members of our family (solar) circle; and, far more than this, elicited the 'Principia' from Newton. When we see Halley's Comet let us think with reverence of this great Englishman and his work.

MONDAY, SEPTEMBER 7.

The Colorado Canyon. By Professor W. M. Davis.

The Grand Canyon of the Colorado, in the plateau of Northern Arizona, is not only impressive as an exhibition of normal erosion in a dry climate, but is even more instructive in presenting a natural geological section in its walls from which one may learn of several periods in the past, during each of which the amount of erosion accomplished was vastly greater than that required in the excavation of the canyon. The plateau is built of a heavy series of horizontal palæozoic strata which rest partly on a body of crystalline schists, partly on a series of east-dipping strata. If one imagine the horizontal strata to be removed, an even surface truncating the crystalline rocks and the inclined series is seen. This is evidently the result of widespread erosion by which the former upward extension of the inclined series and its crystalline foundation were reduced from their original extension. Restoring the lost mass and imagining it turned so as to place the inclined series in a horizontal position, these strata may be stripped off, revealing the remarkably even floor of their crystalline foundation. This floor is also evidently the work of erosion of a formerly greater crystalline mass which may well have once had a mountainous height above what now remains. Further backward in time the history of the rock structures has not yet been traced. The reduction of the ancient crystalline mountains to an even surface must have required a vastly longer time than the erosion of the Grand Canyon, for the erosion of the canyon represents only the good beginning of a cycle of erosion, while the reduction of the ancient mountains to a plain represents the essential completion of a cycle of erosion. The deposition of a heavy series of strata, some 10,000 feet thick, upon the crystalline floor represents another period of time vastly longer than that required for the erosion of the canyon. The tilting of the crystalline foundation and its heavy stratified cover and the erosion of the tilted mass to a plain that truncates its two parts required a third vast period of time. The deposition of the horizontal plateau series, 3,000 feet or more in thickness, required a fourth vast period of time.

A first view of the region would suggest that the erosion of the canyon followed the deposition of the plateau series and the uplift of the total mass; but an examination of the area to the north and east shows the retreating escarpments of overlying series of Mesozoic strata, which seem once to have stretched over the whole plateau area with a thickness of several thousand feet. Their deposition required a fifth vast period of time, and their removal a sixth vast period, and only then was the region uplifted to its present altitude and the erosion of the canyon begun.

At first sight of the huge canyon one is disposed to think that its erosion must have occupied an enormously long chapter of geological time. The chapter was certainly long if measured in years; but if rated on a geological scale it appears to be much shorter than any one of the six chapters into which the geological history of the region is naturally divided. Huge as the canyon is, it is appropriately regarded as a young geographical feature; its magnitude indicates a precocious development rather than a venerable antiquity. Really venerable features are in the buried plains of erosion revealed in the canyon walls.

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References to reports and papers printed in extenso *are given in Italics.*
*An asterisk * indicates that the title only of the communication is given.*
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[P.T.O.

ORDINARY MEMBERS OF THE COUNCIL.

ABNEY, Sir W., K.C.B., F.R.S.
ANDERSON, TEMPEST, M.D., D.Sc.
BOURNE, Professor G. C., D.Sc.
BOWLEY, A. L., M.A.
BRABROOK, Sir EDWARD, C.B.
BROWN, Dr. HORACE T., F.R.S.
BRUNTON, Sir LAUDER, Bart., F.R.S.
CLOSE, Major C. F., R.E., C.M.G.
CRAIGIE, Major P. G., C.B.
DYSON, Professor F. W., F.R.S.
FORSYTH, Professor A. R., F.R.S.
GLAZEBROOK, Dr. R. T., F.R.S.
HALL, A. D., M.A.
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HAWKSLEY, C., M.Inst.C.E.
HOGARTH, D. G., M.A.
MCKENDRICK, Professor J. G., F.R.S.
MITCHELL, Dr. P. CHALMERS, F.R.S.
POULTON, Professor E. B., F.R.S.
PRAIN, Lieut.-Colonel D., C.I.E., F.R.S.
SHERRINGTON, Professor C. S., F.R.S.
SHIPLEY, Dr. A. E., F.R.S.
TUTTON, Dr. A. E. H., F.R.S.
WATTS, Professor W. W., F.R.S.
WOODWARD, Dr. A. SMITH, F.R.S.

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The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past-Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

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The Right Hon. Lord AVEBURY, D.C.L., LL.D., F.R.S., F.L.S.
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Sir Archibald Geikie, K.C.B., Pres.R.S.
Lord Lister, D.C.L., F.R.S.
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PAST GENERAL OFFICERS OF THE ASSOCIATION.

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A. Vernon Harcourt, F.R.S.
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Prof. E. A. Schäfer, F.R.S.
Dr. D. H. Scott, M.A., F.R.S.
Dr. G. Carey Foster, F.R.S.
Dr. J. G. Garson.

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

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1908.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant Secretary, Burlington House, London, W.

Year of Election.

1905. *à Ababrelton, Robert, F.R.G.S. P.O. Box 322, Pietermaritzburg, Natal.
1887. *ABBE, Professor CLEVELAND. Weather Bureau, Department of Agriculture, Washington, U.S.A.
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.
1904. §Acton, T. A. 3 Grove-road, Wrexham.
1898. ‡ACWORTH, W. M., M.A. (Pres. F, 1908.) The Albany, W.

Year of Election.

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.
1904. ‡Adams, W. G. S., M.A. Department of Agriculture, Upper Merrion-street, Dublin.
1869. *Adams, William Grylls, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S. (Pres. A, 1880; Council, 1878–85.) Heathfield, Broadstone, Dorset.
1908. §Adamson, R. Stephen. Emmanuel College, Cambridge.
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.
1908. §Adkin, Robert. 4 Lingard's-road, Lewisham, S.E.
1905. ‡Adle, Henry. P.O. Box 1059, Johannesburg.
1908. *Agar, W. E., M.A. Natural History Department, The University, Glasgow.
1902. ‡Agnew, Samuel, M.D. Bengal-place, Lurgan.
1906. §Aikman, J. A. 6 Glencairn-crescent, Edinburgh.
1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
1890. *Airedale, Lord. Gledhow Hall, Leeds.
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. Broomsberrow Place, Ledbury.
1905. ‡Albright, Miss. Finstal Farm, Finstal, Bromsgrove, Worcestershire.
1907. §Alcock, Dr. N. H. 22 Downshire-hill, Hampstead, N.W.
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, F.S.A. 24 Lawn-crescent, Kew.
1888. *Alexander, Patrick Y. 82 Victoria-street, S.W.
1891. *Alford, Charles J., F.G.S. 15 Great St. Helen's, 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.
1907. *Allorge, M. M., L.èsSc., F.G.S. University Museum, Oxford.
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.
1908. §Anderson, Edgar. Glenavon, Merrion-road, Dublin.

Year of Election.

1885. *ANDERSON, HUGH KERR, M.A., M.D., F.R.S. Caius College, Cambridge.
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. (Council, 1907- ; Local Sec. 1881.) 17 Stonegate, York.
1902. *Anderson, Thomas. Embleton, Osborne Park, Belfast.
1901. *Anderson, Dr. W. Carrick. 8 Windsor-quadrant, Glasgow.
1908. §Anderson, William. Glenavon, Merrion-road, Dublin.
1907. ‡Andrews, A. W. Adela-avenue, West Barnes-lane, New Malden, Surrey.
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., Assoc.Inst.C.E. 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, William. Hillcrest, Oaken, Wolverhampton.
1908. §Armstrong, E. C. R., M.R.I.A., F.R.G.S. Cyprus, Eglinton-road, Dublin.
1903. *ARMSTRONG, E. FRANKLAND, D.Sc., Ph.D. 98 London-road Reading.
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 Sheffield.
1893. *Arnold-Bemrose, H. H., Sc.D., 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. The British School, Rome.
1907. §ASHLEY, W. J., M.A. (Pres. F, 1907), Professor of Commerce in the University of Birmingham. 3 Yateley-road, Edgbaston, Birmingham.
Ashworth, Henry. Turton, near Bolton.
1903. *Ashworth, J. H., D.Sc. 4 Cluny-terrace, Edinburgh.
1890. ‡Ashworth, J. Reginald, D.Sc. 105 Freehold-street, Rochdale.
1905. ‡Askew, T. A. Main-road, Claremont, Cape Colony.

Year of Election.

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.
1908. §Astley, Rev. H. J. Dukinfield, M.A. East Rudham Vicarage, King's Lynn.
1903. ‡Atchison, Arthur F. T., B.Sc. Royal Engineering College, Cooper's Hill, Staines.
1887. ‡Atkinson, Rev. C. Chetwynd, D.D. Ingestre, Ashton-on-Mersey.
1898. *Atkinson, E. Cuthbert. 5 Pembroke-vale, Clifton, Bristol.
1894. *Atkinson, Harold W., M.A. West View, Eastbury-avenue, Northwood, Middlesex.
1906. ‡Atkinson, J. J. Cosgrove Priory, Stony Stratford.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1907. §Atkinson, Robert E. Morland-avenue, Knighton, Leicester.
1881. ‡Atkinson, Robert William, F.C.S. (Local Sec. 1891.) 44 Loudoun-square, Cardiff.
1863. *Attfield, J., M.A., Ph.D., F.R.S., F.C.S. Ashlands, Watford, Herts.
1906. §Auden, Dr. G. A. The Education Office, Edmund-street, Birmingham.
1907. §Auden, H. A., D.Sc. Westwood, Grassendale, Liverpool.
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.

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.
1907. §Badgley, Colonel W. F., Assoc.Inst.C.E., F.R.G.S. Verecroft, Devizes.
1908. *Bagnall, Richard Siddoway. The Groves, Winlaton, Co. Durham.
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. 22 Clarendon-road, Margate.
1905. §Bailey, W. F., C.B. Land Commission, Dublin.
1894. *Baily, Francis Gibson, M.A. Newbury, Colinton, Midlothian.
1878. ‡Baily, Walter. 4 Roslyn-hill, Hampstead, N.W.
1897. §Bain, James. Public Library, Toronto, Canada.
1905. *Baker, Sir Augustine. 56 Merrion-square, Dublin.
1886. §Baker, Harry, F.I.C. Epworth House, Moughland-lane, Runcorn.
1907. §Baldwin, Walter. 5 St. Alban's-street, Rochdale.
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.

Year of Election.

1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1905. ‡Balfour, Mrs. J. Dawyck, Stobo, N.B.
1905. ‡Balfour, Lewis. 11 Norham-gardens, Oxford.
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.
1908. §Ball, T. Elrington. 6 Wilton-place, Dublin.
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. Care of Mrs. Plummer, Prior's-terrace, Tynemouth.
1898. ‡Barker, W. R. 106 Redland-road, Bristol.
1909. §Barlow, Lieut.-Colonel G. N. H. Care of Messrs. Cox & Co., 16 Charing Cross, S.W.
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.R.S., F.G.S. The Red House, Great Stanmore.
1905. §Barnard, Miss Annie T., M.D., B.Sc. 32 Chenies-street-chambers, Gower-street, W.C.
1902. §Barnard, J. E. Park View, Brondesbury Park, N.W.
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.
1907. §Barnes, Professor H. T. McGill University, Montreal, Canada.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E., Professor of Civil Engineering in the University, Glasgow.
1902. *Barr, Mark. Gloucester-mansions, Harrington-gardens, S.W.
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. 6 De Vesci-terrace, Kingstown, Co. Dublin.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Rev. Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.

Year of Election.

1893. *Barrow, George, F.G.S. 28 Jermyn-street, S.W.
1896. §Barrowman, James. Staneacre, Hamilton, N.B.
1908. §Barry, Gerald H. Wiglin Glebe, Carlow, Ireland.
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. Newington House, Edinburgh.
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.
1908. §Barton, Walter John. The College, Winchester.
1904. *Bartrum, C. O., B.Sc. 12 Heath-mansions, Heath-street, Hampstead, N.W.
1845. *Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1888. *Basset, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, N.
1889. ‡Bastable, Professor C. F., M.A., F.S.S. (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. Woodhouse, Wimbledon Park, S.W.
1907. *Bateman, Harry. The University, Manchester.
1884. ‡Bateson, William, M.A., F.R.S. (Pres. D, 1904), Professor of Biology in the University of Cambridge. 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.
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.
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.

Year of Election.

1885. ‡BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, N.W.
1870. ‡BEDDOE, JOHN, M.D., F.R.S. (Council, 1870–75.) The Chantry, Bradford-on-Avon.
1904. *Bedford, T. G., M.A. 13 Warkworth-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.
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.
1900. *Bell, Henry Wilkinson. Beech Cottage, Rawdon, near Leeds.
1870. *BELL, J. CARTER, A.R.S.M. 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.
1908. *Bellamy, Frank Arthur, M.A., F.R.A.S. University Observatory, Oxford.
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 Johannesburg Consolidated Investment Co., P.O. Box 590, 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.
1908. §Benton, Mrs. Evelyn M. Kingswear, Hale, Altrincham, Cheshire.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1894. §BERKELEY, The Earl of, F.R.S., F.G.S. Foxcombe, Boarshill, near Abingdon.
1905. *BERNACCHI, L. C., F.R.G.S. Pound Farm, Upper Long Ditton, Surrey.
1906. *Bernays, Albert Evan. 3 Priory-road, Kew, Surrey.
1898. §Berridge, Miss C. E. 7 Albert-mansions, Lansdowne-road, Croydon.
1894. §BERRIDGE, DOUGLAS, M.A., F.C.S. The College, Malvern.
1908. *Berridge, Miss Emily M. Dunton Lodge, The Knoll, Beckenham.
1908. *Berry, Arthur J. 5 University-gardens, Glasgow.
1904. ‡Berry, R. A. West of Scotland Agricultural College, 6 Blythswood-square, Glasgow.
1905. ‡Bertrand, Captain Alfred. Champel, Geneva.
1862. ‡BESANT, WILLIAM HENRY, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
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.

Year of Election.

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. *Bilsland, Sir William, Bart., J.P. 28 Park-circus, Glasgow.
1908. *Bilton, Edward Barnard. Graylands, Wimbledon Common, S.W.
1887. *Bindloss, James B. Elm Bank, Buxton.
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.
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. 428 Custom House, St. Louis, Mo., U.S.A.
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. (Pres. K, 1908.) St. John's College, Cambridge.
1908. §Blackman, Professor V. H., M.A., Sc.D. The University, Leeds.
1908. §Blake, G. F., J.P. Royal College of Surgeons, Dublin.
1902. ‡Blake, Robert F., F.I.C. 66 Malone-avenue, Belfast.
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, Manchester.
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.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1900. ‡Bodington, Sir Nathaniel, Litt.D. Yorkshire College, Leeds.
1908. §Boeddicker, Otto, Ph.D. Birr Castle Observatory, Birr, Ireland.
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, Muswell Hill, N.
1898. *Bonar, James, M.A., LL.D. (Pres. F, 1898; Council, 1899–1905.) The Mint, Ottawa, Canada.
1908. §Bone, Professor W. A., D.Sc., F.R.S. The University, Leeds.
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.

Year of Election.

1883. ‡Booth, James. Hazelhurst, Turton.
1908. §Booth, Robert, J.P. Bartra Hall, Dalkey, Co. Dublin.
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, Cambridge.
1882. §BORNS, 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., M.Sc., F.I.C., F.C.S., Education Secretary, Somerset County Council, Weston-super-Mare.
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. 26 Arches-road, 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., Rector of the Imperial College of Science and Technology, South Kensington, S.W.
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.
1908. §Bowles, E. Augustus, M.A., F.L.S. Myddleton House, Waltham Cross, Herts.
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.
1892. §BOYS, CHARLES VERNON, F.R.S. (Pres. A, 1903; Council, 1893-99, 1905-08.) 66 Victoria-street, S.W.
1905. ‡Boys, Mrs. C. Vernon. 27 The Grove, Boltons, S.W.

Year of Election.

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. Helena, Alan-road, Wimbledon, S.W.
1905. ‡Bradford, Wager. P.O. Box 5, Johannesburg.
1893. §Bradley, F. L. Ingleside, Malvern Wells.
1904. *Bradley, Gustav. Council Offices, Goole.
1899. *Bradley, J. W., Assoc.M.Inst.C.E. Westminster City Hall, Charing Cross-road, W.C.
1903. *Bradley, O. Charnock, D.Sc., M.D., 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.
1905. §Brakhan, A. Clare Bank, The Common, Sevenoaks.
1906. §Branfield, Wilfred. 5 Victoria-villas, Upperthorpe, Sheffield.
1885 **Bratby, William, J.P. Alton Lodge, Lancaster Park, Harrogate.*
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. 46 Clonmel-road, West Green, Tottenham, N.
1908. §Brickwood, Sir John. Branksmere, Southsea.
1907. *Bridge, Henry Hamilton. North Lodge, Battle, Sussex.
1886. ‡Bridge, T. W., M.A., Sc.D., 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, Cambridge.
1905. ‡Brill, J., Litt.D. Grey College, Bloemfontein, South Africa.
1908. §Brindley, H. H. 4 Devana-terrace, Cambridge.
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. *Brittain, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
1905. *Broadwood, Brigadier-General R. G. The Deodars, Bloemfontein, South Africa.
1905. §Brock, Dr. B. G. P.O. Box 216, Germiston, Transvaal.
1907. ‡Brockington, W. A., M.A. Leicestershire County Council, 38 Bowling Green-street, Leicester.
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.

Year of Election.

1903. ‡BRODRICK, HAROLD, M.A., F.G.S. (Local Sec. 1903.) 7 Aughton-road, Birkdale, Southport.
1904. ‡Bromwich, T. J. I'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., Yorkshire.*
1906. §Brooks, F. T. 102 Mawson-road, Cambridge.
1883. *Brotherton, E. A., M.P. Arthington Hall, Wharfedale, *viâ* Leeds.
1883. *Brough, Mrs. Charles S. 19 Salisbury-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.) 8 Belgrave-crescent, Edinburgh.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1905. §Brown, Professor Ernest William, M.A., D.Sc., F.R.S. Yale University, New Haven, Conn., U.S.A.
1903. ‡Brown, F. W. 6 Rawlinson-road, Southport.
1870. §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.
1908. §Brown, Sidney G. 52 Kensington Park-road, W.
1905. §Brown, Mrs. Sidney G. 52 Kensington Park-road, W.
1908. §Brown, William, B.Sc. 48 Dartmouth-square, Dublin.
1906. §Browne, Charles E., B.Sc. Christ's Hospital, West Horsham.
1900. *Browne, Frank Balfour, M.A., F.R.S.E., F.Z.S. Claremont, Holywood, Co. Down.
1908. §Browne, Rev. Henry, M.A. University College, Dublin.
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 Sir DAVID, C.B., M.B., F.R.S. (Pres. I, 1905.) War Office, 68 Victoria-street, S.W.
1905. ‡Bruce, Lady. 3P Artillery-mansions, Victoria-street, S.W.
1893. ‡Bruce, William S. 11 Mount Pleasant, Joppa, Edinburgh.
1902. ‡*Bruce-Kingsmill, Major J., R.A. Royal Arsenal, Woolwich.*

Year of Election.

1900. *Brumm, Charles. Lismara, Grosvenor-road, Birkdale, Southport.
1896. *Brunner, Right Hon. Sir J. T., Bart., M.P. Druid's Cross, Wavertree, Liverpool.
1868. ‡Brunton, Sir T. Lauder, Bart., M.D., D.Sc., F.R.S. (Council, 1908– .) 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.
1901. ‡Bryce, Thomas H. 2 Granby-terrace, Hillhead, Glasgow.
1902. *Bubb, Miss E. Maude. Ullenwood, near Cheltenham.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
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.
1907. §Burch, George J., M.A., D.Sc. F.R.S. Norham Hall, Oxford.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1905. ‡Burdon, E. R., M.A. Ikenhilde, Royston, Herts.
1894. ‡Burke, John B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Colonel Jeffrey H. 342 Sherbrooke-street West, 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.
1908. §Burnside, W. Snow, D.Sc., Professor of Mathematics in the University of Dublin. 35 Raglan-road, Dublin.
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. ‡Burtt, Arthur H., D.Sc. 4 South View, Holgate, York.
1906. §Burtt, Philip. Swarthmore, 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 Hill, York.
1908. *Bushell, W. F. The Hermitage, Harrow.

Year of Election.

1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1884. *Butterworth, W. Verona, 10 Derbe-road, St. Anne's-on-the-Sea, Lancashire.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1899. ‡Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.

1908. §Cadic, Edouard, D.Litt. Mon Caprice, Pembroke Park, Dublin.
1861. *Caird, James Key, LL.D. 8 Roseangle, Dundee.
1905. ‡Calderwood, J. M. P.O. Box 2295, Johannesburg.
1901. ‡Caldwell, Hugh. Blackwood, Newport, Monmouthshire.
1907. §Caldwell, K. S. St. Bartholomew's Hospital, S.E.
1908. §Caldwell, Colonel R. T., M.A., LL.M., LL.D. Corpus Christi College, Cambridge.
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. 51 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, Professor EDWIN, M.A., LL.D., F.S.S. (Pres. F, 1902.) 46 Wellington-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. 11 Oak-road, Withington, Manchester.
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. ‡Carslaw, H. S., D.Sc., Professor of Mathematics in the University of Sydney, N.S.W.
1868. *Carteighe, Michael, F.C.S., F.I.C. Oriel, Goring, Reading.
1900. *Carter, Rev. W. Lower, M.A., F.G.S. East London College, Mile End-road, E.
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.

Year of Election.

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.
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.
1908. *Cave, Charles J. P., M.A. Ditcham Park, Petersfield.
1886. *Cave-Moyle, Mrs. Isabella. St. Paul's Vicarage, Cheltenham.
Cayley, Digby. Brompton, near Scarborough.
1905. *Challenor, Bromley, M.A. 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.
1908. §Chance, Sir Arthur, M.D. 90 Merrion-square, Dublin.
1907. *Chapman, Alfred Chaston, F.I.C. 8 Duke-street, Aldgate, E.C.
1902. §Chapman, D. L. 10 Parsonage-road, Withington, Manchester.
1899. §Chapman, Professor Sydney John, M.A. Burnage Lodge, Levenshulme, Manchester.
1905. ‡Chassigneux, E. 12 Tavistock-road, Westbourne-park, W.
1903. ‡Chaster, G. W. 42 Talbot-street, Southport.
1904. *Chattaway, F. D., M.A., D.Sc., Ph.D., F.R.S. 22 Park-crescent, Oxford.
1884. *CHATTERTON, GEORGE, M.A., M.Inst.C.E. 6 The Sanctuary, Westminster, S.W.
1886. *CHATTOCK, A. P., M.A., Professor of Experimental Physics in University College, Bristol.
1867. *Chatwood, Samuel, F.R.A.S. Queen's Hotel, Southport.
1904. *Chaundy, Theodore William. 49 Broad-street, Oxford.
1900. §Cheesman, W. Norwood, J.P., F.L.S. The Crescent, Selby.
1874. *Chermside, Lieut.-General Sir H. C., R.E., G.C.M.G., C.B. Newstead Abbey, Nottingham.
1908. §Cherry, Right Hon. R. R. 92 St. Stephen's Green, Dublin.
1879. *Chesterman, W. Belmayne, Sheffield.
1908. §Chill, Edwin, M.D. Westleigh, Mattock-road, Ealing, W.
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. (Pres. E, 1907.) 12 Hallhead-road, Edinburgh.
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.

Year of Election.

1876. *CHRYSTAL, 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.
1901. §Clark, Archibald B., M.A. 16 Comely Bank-street, Edinburgh.
1905. *Clark, Cumberland, F.R.G.S. 29 Chepstow-villas, Bayswater, W.
1907. *Clark, Mrs. Cumberland. 29 Chepstow-villas, Bayswater, W.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
1902. ‡Clark, G. M. South African Museum, Cape Town.
1908. §Clark, James, B.Sc. Newtown School, Waterford, Ireland.
1881. *Clark, J. Edmund, B.A., B.Sc. Asgarth, Riddlesdown-road, Purley, Surrey.
1908. §Clark, John R. W. Brothock Bank House, Arbroath, Scotland.
1901. *Clark, Robert M., B.Sc., F.L.S. 27 Albyn-place, Aberdeen.
1907. *Clarke, E. Russell. 11 King's Bench-walk, Temple, E.C.
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. 5 The Crescent, Mount Radford, 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, Mrs. 2 The University, Glasgow.
1905. §Cleland, J. R. 2 The University, Glasgow.
1902. ‡Clements, Olaf P. Tana, St. Bernard's-road, Olton, Warwick.
1904. §CLERK, DUGALD, F.R.S., M.Inst.C.E. (Pres. G, 1908.) 18 Southampton-buildings, W.C.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1906. §CLOSE, Major C. F., R.E., C.M.G., F.R.G.S. (Council, 1908– .) 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, F.R.S.E. 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.
1908. *Cochrane, Miss Constance. The Downs, St. Neots.
1864. *Cochrane, James Henry. Burston House, Pittville, Cheltenham.
1908. §Cochrane, Robert, I.S.O., LL.D., F.S.A. 17 Highfield-road, Dublin.
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.
1908. §Coffey, Denis J., M.B. 2 Arkendale-road, Glenageary, Co. Dublin.
1898. ‡Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *COFFIN, WALTER HARRIS, F.C.S. Passaic, Kew.

Year of Election.

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, F.R.A.S. 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.
1893. ‡Collinge, Walter E. The University, Birmingham.
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. Churchfield, 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 Sec. 1907.) Millstone-lane, Leicester.
1905. *Combs, Rev. Cyril W., M.A. Elverton, Castle-road, Newport, Isle of Wight.
1871. *Connor, Charles C. 10 College-gardens, 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. The Pines, Langland-gardens, Hampstead, N.W.
1883. ‡Cooley, George Parkin. Constitutional Club, Nottingham.
1899. *Coomaraswamy, A. K., D.Sc., F.L.S., F.G.S. Broad Campden, Gloucestershire.
1902. *Coomaraswamy, Mrs. A. K. Broad Campden, Gloucestershire.
1903. §Cooper, Miss A. J. 22 St. John-street, Oxford.
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1907. §Cooper, William. Education Offices, Becket-street, Derby.
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. 10 Wynnstay-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. Abbotsford House, Waverley-street, Nottingham.
1889. ‡CORNISH, VAUGHAN, D.Sc., F.R.G.S. 31 Kensington Gardens-square, W.

Year of
Election.

1905. ‡Cornish-Bowden, A. H. Surveyor-General's Office, Cape Town.
1884. *Cornwallis, F. S. W., 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, Grahamstown, Cape Colony.
1908. *Costello, John Francis, B.A. The Rectory, Ballymackey, Nenagh, Ireland.
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.
1908. §Cotton, Alderman W. F., D.L., J.P. Hollywood, Co. Dublin.
1905. ‡Cottrill, G. St. John, P.O. Box 4829, Johannesburg.
1904. ‡Coulter, G. G. 28 Pall Mall, S.W.
1908. §Courtenay, Colonel Arthur H., C.B., D.L. United Service Club, Dublin.
1896. ‡COURTNEY, Right Hon. Lord. (Pres. F, 1896.) 15 Cheyne-walk, Chelsea, S.W.
1905. ‡Cousens, R. L. P.O. Box 4261, Johannesburg.
1908. §Cowan, P. C., B.Sc., M.Inst.C.E. 33 Ailesbury-road, Dublin.
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.
1899. ‡Cowper-Coles, Sherard, Assoc.M.Inst.C.E. 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.*
1908. §Craig, James, M.D. 18 Merrion-square North, Dublin.
1884. §CRAIGIE, Major P. G., C.B., F.S.S. (Pres. F, 1900; Council, 1908– .) West Wellow, Romsey, Hampshire.
1906. ‡Craik, Sir Henry, K.C.B., LL.D., M.P. 5A Dean's-yard, Westminster, S.W.
1908. *Cramer, W., Ph.D., D.Sc. Physiological Department, The University, Edinburgh.
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. Woodheyes-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, Colinton-road, Edinburgh.
1905. ‡Crawford, W. C., jun. 1 Lockharton-gardens, Colinton-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.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.

Year of Election.

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. Spurs, Styall, Handforth, Manchester.
1904. ‡Crilly, David. 7 Well-street, Paisley.
1880. *Crisp, Sir Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1908. §Crocker, J. Meadmore. Albion House, Bingley, Yorkshire.
1905. §Croft, Miss Mary. 17 Pelham-crescent, S.W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1908. §Crofts, D. G. Cadastral Survey, Nairobi, East African Protectorate.
1878. *Croke, John O'Byrne, M.A. Clouneagh, Ballingarry-Lacy, Co. Limerick.
1903. *Crompton, Holland. Oaklyn, Cross Oak-road, Berkhamsted.
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.
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., F.R.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 10 Crediton-road, West Hampstead, N.W.
1908. §Crossley, F. W. 30 Molesworth-street, Dublin.
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.
1890. *Crowley, Ralph Henry, M.D. 116 Manningham-lane, Bradford.
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, 1902–08), 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.

Year of Election.

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.

1908. §Currelly, C. T., M.A., F.R.G.S. United Empire Club, 117 Piccadilly, W.

1892. *Currie, James, M.A., F.R.S.E. Larkfield, Wardie-road, Edinburgh.

1905. §Currie, Dr. O. J. Manor House, Mowbray, Cape Town.

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. Rosslynlee, Woodside Green, South Norwood, S.E.

1881. §Cushing, Thomas, F.R.A.S. Rosslynlee, Woodside Green, South Norwood, S.E.

1907. ‡Cushny, Arthur R., M.D., F.R.S., Professor of Pharmacology in University College, Gower-street, W.C.

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.

1889. *Dale, Miss Elizabeth. Garth Cottage, Oxford-road, Cambridge.

1906. §Dale, William, F.S.A., F.G.S. The Lawn, Archer's-road, Southampton.

1907. ‡DALGLIESH, RICHARD, J.P., D.L. Ashfordby Place, near Melton Mowbray.

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.

1901. ‡Daniell, G. F., B.Sc. Woodberry, Oakleigh Park, N.

1896. §Danson, F. C. Liverpool and London Chambers, Dale-street, Liverpool.

1849. *Danson, Joseph. Montreal, Canada.

1897. §Darbishire, F. V., B.A., Ph.D. South-Eastern Agricultural College, Wye, Kent.

1903. §Darbishire, Dr. Otto V. The University, Manchester.

1904. *Darwin, Charles Galton. Newnham Grange, Cambridge.

1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.

1882. *DARWIN, FRANCIS, M.A., M.B., LL.D., D.Sc., F.R.S., F.L.S. (PRESIDENT; 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, Pres. R.G.S. (Pres. E, 1896; Council, 1899–1905.) 12 Egerton-place, South Kensington, S.W.

Year of Election.

1882. ‡Darwin, W. E., B.A., F.G.S. 11 Egerton-place, S.W.
1908. §Davey, H. 15 Victoria-road, Brighton.
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., F.G.S. 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. P.O. Box 898, Johannesburg.
1885. *Davis, Rev. Rudolf. 4 Alexandra-terrace, Gloucester.
1905. ‡Davy, Mrs. Alice Burtt. P.O. Box 434, Pretoria.
1905. ‡Davy, Joseph Burtt, 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, William Clarke. 16 Parliament-street, Hull.
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, Captain 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 Schlangenweg, Cassel, Hessen.
1893. *Deeley, R. M. Melbourne House, Osmaston-road, Derby.
1878. ‡Delany, Very Rev. William, LL.D. University College, Dublin.
1908. §Delf, Miss E. M. Westfield College, Hampstead, N.W.
1907. ‡De Lisle, Mrs. Edwin. Charnwood Lodge, Coalville, Leicestershire.
1896. ‡Dempster, John. Tynron, Noctorum, Birkenhead.
1902. ‡Dendy, Arthur, D.Sc., F.R.S., F.L.S., Professor of Zoology in King's College, London, W.C.
1908. §Dennehy, W. F. 23 Leeson-park, Dublin.
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.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, W.

Year of Election.

1907. *Desch, Cecil H., D.Sc., Ph.D. 93 Mount Pleasant-road, South Tottenham, N.
1908. §Despard, Miss Kathleen M. 39 Twyford-avenue, West Acton.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1903. ‡*Devereux, Rev. F. R. Price. Drachenfeld, Tenison-avenue, Cambridge.*
1868. *DEWAR, Sir JAMES, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., V.P.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. (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. ‡Dewhirst, Miss May. Pembroke House, Oxford-road, Colchester.
1901. ‡Dick, George Handasyde. 31 Hamilton-drive, Hillhead, Glasgow.
1908. §Dicks, Henry. Haslecourt, Horsell, Woking.
1904. ‡Dickson, Charles Scott, K.C., LL.D. Carlton Club, Pall Mall, S.W.
1881. ‡Dickson, Edmund, M.A., F.G.S. Claughton House, Garstang, R.S.O., Lancashire.
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.
1908. §Dines, J. S. 17 Denbigh-street, Pimlico, S.W.
1901. §Dines, W. H., F.R.S. Pyrton Hill, Watlington.
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.
1900. ‡Dixon, A. Francis, Sc.D., Professor of Anatomy in the University of Dublin.
1905. ‡Dixon, Miss E. K. Fern Bank, St. Bees, S.O.
1908. §Dixon, Edward K., M.E., M.Inst.C.E. Castlebar, Co. Mayo.
1888. ‡Dixon, Edward T. Racketts, Hythe, Hampshire.
1908. *Dixon, Ernest. Pwllcrochan, Pembroke.
1900. *Dixon, Major 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., F.R.S., Professor of Botany in the University of Dublin. Clevedon, Temple-road, Dublin.
1908. *Dixon, Walter, F.R.M.S. Derwent, 30 Kelvinside-gardens, Glasgow.
1907. *Dixon, Professor Walter E. The Museums, Cambridge.
1902. ‡Dixon, W. V. Scotch Quarter, Carrickfergus.
1896. §Dixon-Nuttall, F. R. Ingleholme, Eccleston Park, Prescot.
1890. ‡Dobbie, James J., D.Sc., F.R.S., Director of the Museum of Science and Art, Edinburgh.

Year of Election.

1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. Castle Dobbs, Carrickfergus, Co. Antrim.
1902. ‡Dobbs, F. W. 2 Willowbrook, Eton, Windsor.
1905. ‡Dobson, Professor J. H. Transvaal Technical Institute, Johannesburg.
1908. §Dodd, Hon. Mr. Justice. 26 Fitzwilliam-square, Dublin.
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, M.A. The University, Birmingham.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1901. §Donnan, F. G., M.A., Ph.D., Professor of Physical Chemistry. The University, Liverpool.
1905. ‡Donnan, H. Allandale, Claremont, Cape Colony.
1908. §Donnelly, Most Rev. Dr. Nicholas, Bishop of Canea. St. Mary's, Haddington-road, Dublin.
1905. ‡Donner, Arthur. Helsingfors, Finland.
1905. §Donovan, Surgeon-General William, C.B. Army Headquarters, Pretoria.
1905. §Dornan, Rev. S. S. P.O. Box 510, Bulawayo, South Rhodesia, South Africa.
1863. *Doughty, Charles Montagu. 26 Grange-road, Eastbourne.
1909. *Douglas, James, 99 John-street, New York, U.S.A.
1905. ‡Douglas-McMillan, Mrs. A. 31 Ford-street, Jeppestown, Transvaal.
1884. ‡Dove, Miss Frances. Wycombe Abbey School, Buckinghamshire.
1903. ‡Dow, Miss Agnes R. 81 Park-mansions, Knightsbridge, S.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. 11 Embankment-gardens, Chelsea, S.W.
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.
1908. §Droop, J. P. 11 Cleveland-gardens, Hyde Park, W.
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.
1907. §Drysdale, Charles V. Northampton Institute, Clerkenwell, E.C.
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.
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, F.R.S. 47 Hans-place, S.W.
1906. ‡Dudgeon, Gerald C., Superintendent of Agriculture for British West Africa. Bathurst, Gambia, British West Africa.
1904. *Duffield, W. Geoffrey. Physical Laboratory, The University, Manchester.
1890. ‡Dufton, S. F. Trinity College, Cambridge.

Year of Election.

1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.

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, 1905-08), Director of the Imperial Institute, S.W.

1905. §Dutton, C. L. O'Brien. High Commissioner's Office, Johannesburg.

1895. *DWERRYHOUSE, ARTHUR R., D.Sc., F.G.S. 10 Ashwood-villas, 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.

1908. *Eddington, A. S. Royal Observatory, Greenwich, S.E.

1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.

1858. *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.

1908. §Edmondson, Thomas. Creevagh, Orwell Park, Dublin.

1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.

1884. *Edmunds, James, M.D. 23 Sussex-square, Kemp Town, Brighton.

1901. *EDRIDGE-GREEN, F. W., M.D., F.R.C.S. Hendon Grove, Hendon, N.W.

1899. §Edwards, E. J., Assoc.M.Inst.C.E. 290 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.

1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.

1901. ‡Eggar, W. D. Willowbrook, Eton, Windsor.

1907. *Elderton, W. Palin. Allington, Telford-avenue, S.W.

Year of Election.

1890. §Elford, Percy. St. John's College, Oxford.
1885. *ELGAR, FRANCIS, LL.D., F.R.S., F.R.S.E., M.Inst.C.E. 18 Cornwall-terrace, Regent's Park, N.W.
1901. *Elles, Miss Gertrude L., D.Sc. 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. Church-square, 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, D.Sc., Ph.D. Technical College, Glasgow.
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1906. §ELLIS, HERBERT. 120 Regent-road, Leicester.
1880. *ELLIS, JOHN HENRY. (Local Sec. 1883.) 10 The Crescent, Plymouth.
1891. §Ellis, Miss M. A. Care of Miss Rice, 11 Canterbury-road, Oxford.
1906. ‡ELMHIRST, CHARLES E. (Local Sec. 1906.) 29 Mount-vale, York.
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.
1908. §Evans, Rev. Henry, D.D. Malvina, Howth, Co. Dublin.
1887. *Evans, Mrs. Isabel. Hoghton Hall, Hoghton, near Preston.
1883. *Evans, Mrs. James C. Casewell Lodge, Llanwrtyd Wells, South Wales.
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.
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.

Year of Election.

1876. *Ewing, James Alfred, C.B., 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.
1908. §Falconer, Robert A., M.A. 44 Merrion-square, Dublin.
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Cheshire.
1902. §Fallaize, E. N., M.A. Vinchelez, Chase Court-gardens, Windmill-hill, Enfield.
1907. *Fantham, H. B., D.Sc. 30 Salisbury-road, West Ealing, W.
1898. ‡Faraday, Miss Ethel R., M.A. Ramsay Lodge, Levenshulme, near Manchester.
1902. §Faren, William. 11 Mount Charles, Belfast.
1892. *Farmer, J. Bretland, M.A., F.R.S., F.L.S. (Pres. K, 1907), Professor of Botany, Royal College of Science, 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 Hargreave. 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. *Fearnsides, Edwin G., B.A., B.Sc. 56 Gore-road, South Hackney, E.
1901. *Fearnsides, W. G., M.A., F.G.S. Sidney Sussex College, Cambridge.
1905. §Feilden, Colonel H. W., C.B., F.G.S. 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.*
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, Hon. John, C.M.G. Calton Lodge, Cinnamon-gardens, Colombo, Ceylon.
1901. ‡Ferguson, R. W. Municipal Technical School, the Gamble Institute, St. Helens, Lancashire.
1863. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1905. *Ferrar, H. T. Survey Department, Giza, Egypt.

Year of Election.

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.
1907. §Fields, Professor J. C. The University, Toronto, Canada.
1906. §Filon, L. N. G., D.Sc. Vega, Blenheim Park-road, Croydon.
1883. *Finch, Gerard B., M.A. Howes Close, 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 Victoria University, Manchester. Ruperra, Victoria Park, Manchester.
1902. ‡Finnegan, J., M.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., 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.
1908. §Flavelle, Miss Ruth. 7 Alexandra House, St. Mary's-terrace, Paddington, W.
1904. §Fleming, 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.
1908. *Fletcher, W. H. B. Aldwick Manor, Bognor, Sussex.
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. Care of R. H. Hooker, Esq., 3 Clement's Inn, W.C.
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.
1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, S.W.

Year of Election.

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. Synod Hall, Castle-terrace, Edinburgh.
1890. ‡FORD, J. RAWLINSON. (Local Sec. 1890.) Quarry Dene, Weetwood-lane, Leeds.
1875. *FORDHAM, Sir HERBERT 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; Council, 1907-), 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.
1908. *Foster, John Arnold. 11 Hills-place, Oxford Circus, N.W.
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.) Cross Keys House, 56 Moorgate-street, E.C.
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. Old Way House, Wellington, Somerset.
1908. §Foxley, Miss Barbara, M.A. 5 Clarence-road, Withington, Manchester.
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.
1907. §Fraine, Miss Ethel de. Whitelands College, King's-road, Chelsea, S.W.
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. 18 Northbrook-road, Dublin.
1908. §Fraser, Mrs. Alexander. 18 Northbrook-road, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. (Local Sec. 1885). 232 Union-street, Aberdeen.
1906. *FRASER, Miss HELEN C. I., D.Sc., F.L.S. University College, Nottingham.
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.
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. 100 Victoria-street, S.W.
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. 77 Chatsworth-road, Brondesbury, 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.
1908. §Fry, M. W. J., M.A. 39 Trinity College, Dublin.
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
1906. §Gajjar, Professor T. K., M.A. Techno-Chemical Laboratory, near Girgaum Tram Terminus, Bombay.
1885. *Gallaway, 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.
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., F.R.S. 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.
1905. ‡Garlick, John. Thornibrae, Green Point, Cape Town.
1905. ‡Garlick, R. C. Thornibrae, Green Point, Cape Town.

Year of Election.

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., D.Sc., F.Z.S., Professor of Zoology in the University of Leeds.

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, K.C.B., LL.D., D.Sc., Pres.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.

1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.

Year of Election.

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. Reform Club, Pall Mall, S.W.
1878. ‡Giles, Oliver. Brynteg, The Crescent, Bromsgrove.
1871. *GILL, Sir DAVID, K.C.B., LL.D., D.Sc., F.R.S., Hon.F.R.S.E. (PRESIDENT, 1907.) 34 De Vere-gardens, Kensington, W.
1902. ‡Gill, James F. 72 Strand-road, Bootle, Liverpool.
1908. §Gill, T. P. Department of Agriculture and Technical Instruction for Ireland, Dublin.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1907. §Gilmour, S. C. 3 Vernon-chambers, Southampton-row, W.C.
1908. §Gilmour, T. L. 1 St. John's Wood Park, N.W.
1893. *Gimingham, Edward. Croyland, Clapton Common, 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.
1878. ‡GOFF, JAMES. (Local Sec. 1878.) 29 Lower Leeson-street, Dublin.
1908. *Gold, Ernest, M.A. 3 Devana-terrace, Cambridge.
1906. ‡GOLDIE, Sir GEORGE D. T., K.C.M.G., D.C.L., F.R.S. (Pres. E, 1906; Council, 1906-07.) 44 Rutland-gate, S.W.
1898. ‡Goldney, F. Bennett, F.S.A. Goodnestone Park, Dover.
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.
1907. §Goodrich, E. S., M.A., F.R.S., F.L.S. Merton College, Oxford.
1884. *Goodridge, Richard E. W. Coleraine, Minnesota, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1905. ‡GOOLD-ADAMS, Major Sir H. J., G.C.M.G., C.B. Government House, Bloemfontein, South Africa.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's-mansions, Westminster, S.W.

Year of Election.

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.
1875. *Gotch, Francis, M.A., D.Sc., F.R.S. (Pres. I, 1906; Council, 1901–07), 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.
1908. §Grabham, G. W., M.A., F.G.S. Khartoum, Sudan.
1886. ‡Grabham, Michael C., M.D. Madeira.
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.
1908. *Grant, W. L. 10 Park-terrace, Oxford.
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. 99 Grosvenor-road, S.W.
1904. ‡Gray, Rev. H. B., D.D. The College, Bradfield, Berkshire.
1892. *Gray, James Hunter, M.A., B.Sc. 3 Crown Office-row, Temple, E.C.
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.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
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. The Old Gardens, Cardigan-road, Headingley, Leeds.
1904. §Green, F. W. 5 Wordsworth-grove, 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.
1908. §Green, Rev. William Spotswood, C.B., F.R.G.S. 5 Cowper-villas, Cowper-road, Dublin.
1882. ‡Greenhill, Sir 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.

Year of Election.

1898. *Greenly, Edward, F.G.S. 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. (Pres. C, 1907), Professor of Geology in the University of Glasgow.
1896. *Gregory, Professor R. A., F.R.A.S. Dell Quay House, near Chichester.
1904. *Gregory, R. P., M.A. St. John's College, Cambridge.
1881. ‡Gregson, William, F.G.S. 106 Victoria-road, Darlington.
1836. Griffin, S. F. Albion Tin Works, York-road, N.
1894. *Griffith, C. L. T., Assoc.M.Inst.C.E. Municipal Offices, Madras.
1908. §Griffith, John P. Rathmines Castle, Rathmines, Dublin.
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.
1847. ‡Griffiths, Thomas. The Elms, Harborne-road, Edgbaston, Birmingham.
1903. ‡Griffiths, Thomas, J.P. 101 Manchester-road, Southport.
1888. *Grimshaw, James Walter, M.Inst.C.E. St. Stephen's Club, Westminster, S.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. §Guttmann, Leo F., Ph.D. 18 Aberdare-gardens, N.W.

1905. ‡Hacker, Rev. W. J. Edendale, Pietermaritzburg, South Africa.
1881. *Haddon, Alfred Cort, M.A., D.Sc., F.R.S., F.Z.S. (Pres. H, 1902, 1905; Council, 1902-08.) Inisfail, Hills-road, Cambridge.
1905. ‡Haddon, Miss. Inisfail, Hills-road, Cambridge.
1888. *Hadfield, Sir 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.
1894. ‡Haldane, John Scott, M.A., M.D., F.R.S. (Pres. I, 1908), Reader in Physiology in the University of Oxford. Jesus College, Oxford.
1899. ‡Hall, A. D., M.A. (Council, 1908-), Director of the Rothamsted Experimental Station, Harpenden, Herts.
1903. ‡Hall, E. Marshall, K.C. 75 Cambridge-terrace, W.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.

Year of Election.

1883. *Hall, Miss Emily. 63 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.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1908. *Hall, Wilfred, Assoc.M.Inst.C.E. 9 Prior's-terrace, Tynemouth, Northumberland.
1891. *Hallett, George. Cranford, Victoria-square, 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.
1905. ‡Halliburton, Mrs. Church Cottage, 17 Marylebone-road, N.W.
1904. *Hallidie, A. H. S. Avondale, Chesterfield-road, Eastbourne.
1908. §Hallitt, Mrs. Steeple Grange, Wirksworth.
1908. *Hamel, Egbert Alexander de. Middleton Hall, Tamworth.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1904. *Hamel de Manin, Anna Countess de. 35 Circus-road, N.W.
1906. ‡Hamill, John Molyneux, M.A., M.B. 14 South-parade, Chiswick.
1906. ‡Hamilton, Charles I. 88 Twyford-avenue, Acton.
1885. ‡Hamilton, David James, M.B., F.R.S., Professor of Pathology in the University of 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.
1878. §Hance, E. M. Care of J. Hope Smith, Esq., 3 Leman-street, E.C.
1905. *Hancock, Strangman. Plas Uchaf, Abergele, North Wales.
1890. ‡*Hankin, Ernest Hanbury. St. John's College, Cambridge.*
1886. §Hansford, Charles, J.P. Englefield House, Dorchester.
1906. §Hanson, David. Salterlee, Halifax, Yorkshire.
1904. §Hanson, E. K. Woodthorpe, Royston Park-road, Hatch End, Middlesex.
1902. ‡Harbison, Adam, B.A. 5 Ravenhill-terrace, Ravenhill-road, Belfast.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., D.Sc., F.R.S., V.P.C.S. (GEN. SEC. 1883–97; Pres. B, 1875; Council, 1881–83.) St. Clare, Ryde, Isle of Wight.
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.

Year of Election.

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., Sc.D., F.R.S. (Pres. D, 1908.) King's College, Cambridge.
1906. ‡Harper, J. B. 16 St. George's-place, York.
1842. *Harris, G. W. Millicent, South Australia.
1889. ‡Harris, H. Graham, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1903. ‡Harris, Robert, M.B. Queen's-road, 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.
1885. ‡Hart, Colonel C. J. (Local Sec. 1886.) Highfield Gate, Edgbaston, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1903. *Hart, Thomas Clifford. Brooklands, Blackburn.
1907. §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. 10 Elgin-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. 2 Halsey-street, Cadogan-gardens, S.W.
1889. ‡Hatch, F. H., Ph.D., F.G.S. Cowley Place, Cowley, Middlesex.
1903. ‡Hathaway, Herbert G. 45 High-street, Bridgnorth, Salop.
1904. *Haughton, W. T. H. The Highlands, Great Barford, St. Neots.
1908. §Havelock, T. H. St. John's College, Cambridge.
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.

Year of Election.

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. *HAYCRAFT, 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.*
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. Greyfriars, Southwold, Suffolk.
1908. §Heath, J. St. George, B.A. Woodbrooke Settlement, Selby Oak, near Birmingham.
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, I.S.O. 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.
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, Sidcup, Kent.
1908. §Hemmy, Professor A. S., B.A., M.Sc. Care of Dr. Davidson, Clavell House, Belvedere, Kent.
1899. ‡Hemsalech, G. A., D.Sc. The Owens College, Manchester.
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.
1907. ‡Henderson, H. F. 46 Clarendon Park-road, Leicester.
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.

Year of Election.

1904. §Hepworth, Commander M. W. C., C.B., R.N.R. Meteorological Office, Victoria-street, S.W.

1892. *HERBERTSON, A. J., M.A., Ph.D., Reader in Geography in the University of Oxford. 43 Banbury-road, 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., F.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.

1393. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.

1875. ‡HEREFORD, The Right Rev. JOHN PERCIVAL, D.D., LL.D., Lord Bishop of. (Pres. L, 1904.) The Palace, Hereford.

1908. *Herring, Dr. Percy T. Physiological Department, The University, Edinburgh.

1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.

1900. *Herschel, Rev. J. C. W. Bracknell, Berkshire.

1905. ‡Hervey, Miss Mary F. S. 22 Morpeth-mansions, S.W.

1903. *HESKETH, CHARLES H. FLEETWOOD, M.A. The Rookery, North Meols, Southport.

1895. §Hesketh, James. Scarisbrick Avenue-buildings, 233 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.*

1908. §Hewitt, C. Gordon. The University, Manchester.

1896. §Hewitt, David Basil, M.D. Oakleigh, Northwich, Cheshire.

1903. ‡Hewitt, E. G. W. 87 Princess-road, Moss Side, Manchester.

1903. ‡Hewitt, John Theodore, M.A., D.Sc., Ph.D. 7 The Avenue, Surbiton, Surrey.

1882. *HEYCOCK, CHARLES T., M.A., F.R.S. 3 St. Peter's-terrace, Cambridge.

1883. ‡Heyes, Rev. John Frederick, M.A., F.R.G.S. St. Barnabas Vicarage, 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, C.B., LL.B., F.S.S. (Pres. F, 1899; Council, 1904–06.) H.M. Treasury, Whitehall, S.W.

1907. ‡HILEY, E. V. (Local Sec. 1907.) Town Hall, Birmingham.

1885. *HILL, ALEXANDER, M.A., M.D. Downing College, Cambridge.

1903. *HILL, ARTHUR W., M.A., F.L.S. Royal Gardens, Kew.

1906. §Hill, Charles A., M.A., M.B. 13 Rodney-street, Liverpool.

1881. *HILL, Rev. EDWIN, M.A. The Rectory, Cockfield, Bury St. Edmunds.

1908. §Hill, James P. Zoological Laboratory, University College, W.C.

Year of Election.

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-lane, N.W.
1885. *Hillhouse, William, M.A., F.L.S., Professor of Botany in the University of Birmingham. 43 Calthorpe-road, Edgbaston, Birmingham.
1907. *Hills, Major E. H., C.M.G., R.E., F.R.G.S. (Pres. E, 1908.) 32 Prince's-gardens, S.W.
1903. *Hilton, Harold. 73 Platt's-lane, Hampstead, N.W.
1903. *Hind, Wheelton, M.D., 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.
1898. §Hinds, Henry. 57 Queen-street, Ramsgate.
1908. §Hinkett, Felix E. Birchfield, Omagh, Ireland.
1900. §Hinks, Arthur R., M.A. The Observatory, Cambridge.
1903. *Hinmers, Edward. Glentwood, South Downs-drive, Hale, Cheshire.
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.
1907. §Hobson, Mrs. Mary. 6 Hopefield-avenue, Belfast.
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. (Pres. H, 1907; Council, 1907– .) Chapel Meadow, Forest Row, Sussex.
1894. ‡*Hogg, A. F., M.A.* 13 *Victoria-road, Darlington.*
1908. §Hogg, Right Hon. Jonathan. Stratford, Rathgar, Co. Dublin.
1907. ‡Holden, Colonel H. C. L., R.A., F.R.S. Gifford House, Blackheath, S.E.
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. Leithen, Newnham-road, Bedford.

Year of Election.

1905. ‡Hollway, H. C. Schunke. Plaisir de Merle, P.O. Simondium, *viâ* Paarl, South Africa.
1883. *Holmes, Mrs. Basil. 23 Corfton-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 Clement's Inn, W.C.
1908. *Hooper, Frank Henry. Clare College, Cambridge.
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.
1901. *Hopkinson, Bertram, M.A., F.R.S.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. 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.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.
1908. §Horton, F. St. John's College, Cambridge.
1884. *Hotblack, G. S. Brundall, Norwich.
1899. ‡Hotblack, J. T., F.G.S. 45 Newmarket-road, Norwich.
1906. *Hough, Miss Ethel M. Codsall Wood, near Wolverhampton.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, 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.
1908. §Houston, David, F.L.S. Royal College of Science, Dublin.
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., F.R.A.S. Public Museum, Weston Park, Sheffield.

Year of
Election.

1903. *Howarth, James H., F.G.S. Somerley, Rawson-avenue, Halifax.
1907. §Howarth, O. J. R., M.A. 25 St. Leonard's-terrace, Chelsea, S.W.
1905. ‡Howick, Dr. W. P.O. Box 503, Johannesburg.
1901. ‡Howie, Robert Y. 3 Greenlaw-avenue, Paisley.
1863. ‡Howorth, Sir H. H., K.C.I.E., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.
1887. §Hoyle, William E., M.A., D.Sc. (Pres. D, 1907.) 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. 34 Birdhurst-road, Croydon.
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., F.R.G.S. 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.
1905. §Hume, D. G. W. P.O. Box 1132, Johannesburg.
1901. ‡Hume, John H. Toronto, Canada; and 63 Bridgegate, Irvine.
1904. *Humphreys, Alexander C., Sc.D., LL.D., President of the Stevens Institute of Technology, Hoboken, New Jersey, U.S.A.
1907. §Humphries, Albert E. Coxe's Lock Mills, Weybridge.
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.
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. 17 St. John's Wood Park, Finchley-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.
1908. §Hutton, Lucius O. Wyckham, Dundrum, Co. Dublin.
1901. *Hutton, R. S., D.Sc. West-street, Sheffield.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman, H. H. Francis. 5 Warwick-road, Earl's Court, S.W.

1908. §Idle, George. 43 Dawson-street, Dublin.
1883. ‡Idris, T. H. W., M.P. 110 Pratt-street, Camden Town, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.

Year of Election.

1906. ‡Iliffe, J. W. Oak Tower, Upperthorpe, Sheffield.
1885. ‡im Thurn, Sir Everard F., C.B., K.C.M.G. Colombo, Ceylon.
1888. *Ince, Surgeon-Major John, M.D. Montague House, Swanley, Kent.
1907. §Ingham, Charles B. Moira House, Eastbourne.
1905. ‡Ingham, W. Engineer's Office, Sand River, Uitenhage.
1893. ‡Ingle, Herbert. Department of Agriculture, Pretoria.
1901. ‡Inglis, John, LL.D. 4 Prince's-terrace, Dowanhill, Glasgow.
1905. §Innes, R. T. A., F.R.A.S. Meteorological Observatory, Johannesburg.
1901. *Ionides, Stephen A. Rydens Croft, Walton-on-Thames.
1882. §Irving, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1908. §Irwin, Alderman John. 33 Rutland-square, Dublin.
1905. ‡*Iwasaki, Koyata. Pembroke College, Cambridge.*

1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The University, Glasgow.
1883. *Jackson, Professor A. H., B.Sc. 349 Collins-street, Melbourne, Australia.
1903. §Jackson, C. S. Royal Military Academy, Woolwich, S.E.
1883. *Jackson, F. J. 35 Leyland-road, Southport.
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.
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, M.Inst.C.E., F.R.S.E., 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., M.A., F.R.S., Professor of Applied Mathematics in Princeton University, Princeton, New Jersey, U.S.A.
1897. ‡Jeffrey, E. C., B.A. The University, Toronto, Canada.
1908. *Jenkin, Arthur Pearse, F.R.Met.Soc. Trewirgie, Redruth.
1903. ‡Jenkinson, J. W. The Museum, Oxford.

Year of Election.

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, M.A., B.Sc. Woodhill, Rhiwbeina, near Cardiff.
1907. *Jevons, Miss H. W. 19 Chesterford-gardens, Hampstead, N.W.
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., Hon. Sec. R.G.S. Branksome, Saffrons-road, Eastbourne.
1883. ‡JOHNSTON, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. 27 Chester-terrace, Regent's Park, N.W.
1908. §Johnston, Swift Paine. 1 Hume-street, Dublin.
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. (Pres. C, 1908), 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, Embsay, 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.
1905. ‡Jones, Miss Parnell. The Rectory, Llanddewi Skirrid, Abergavenny, Monmouthshire.
1901. ‡Jones, R. E., J.P. Oakley Grange, Shrewsbury.
1902. ‡Jones, R. M., M.A. Royal Academical Institution, Belfast.
1908. §Jones, R. Pugh, M.A. County School, Holyhead, Anglesey.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. (Pres. C, 1891.) Pen-bryn, Chesham Bois-lane, Chesham, Bucks.
1875. *Jose, J. E. Ethersall, Tarbock-road, Huyton, Lancashire.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, S.W.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, Hon. Mrs. St. John's Croft, Winchester.
1905. ‡Judd, Miss Hilda M., B.Sc. Berrymead, 6 Lichfield-road, Kew.

Year of Election.

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., D.Sc., F.I.C. Government Analytical Laboratory, Parliament-street, Cape Town.

1888. ‡Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. Pen-y-Coed, Pritchatts-road, Birmingham.
1904. ‡Kayser, Professor H. The University, Bonn, Germany.
1892. ‡KEANE, CHARLES A., Ph.D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
1908. §Keeble, Frederick, Sc.D. University College, Reading.
1878. **Kelland, W. H. 80 Lothian-road, S.W.*
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1908. §Kelly, Malachy. Ard Brugh, Dalkey, Co. Dublin.
1908. §Kelly, Captain Vincent Joseph. Montrose, Donnybrook, Co. Dublin.
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.
1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1893. *Kemp, John T., M.A. 4 Cotham-grove, Bristol.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
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.
1908. §Kennedy, William. 40 Trinity College, Dublin.
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.
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. Balek Papan, Koltei, 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, Grahamstown, Cape Colony.
1902. §Kidd, George. Greenhaven, Malone Park, Belfast.
1906. ‡Kidner, Henry, F.G.S. 78 Gladstone-road, Watford.

Year of Election.

1886. §KIDSTON, ROBERT, LL.D., 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, J.P. 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, East Grinstead.
1883. *King, Joseph. Sandhouse, Witley, Godalming.
1908. §King, Professor L. A. L., M.A. St. Mungo's College Medical School, Glasgow.
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. Royal Anthropological Institute, 3 Hanover-square, W.
1900. ‡KIPPING, Professor F. STANLEY, D.Sc., Ph.D., F.R.S. (Pres. B, 1908.) University College, Nottingham.
1899. *Kirby, Miss C. F. 74 Kensington Park-road, W.
1907. §Kirby, William Forsell, F.L.S. Hilden, 46 Sutton Court-road, Chiswick, W.
1905. ‡Kirkby, Reginald G. P.O. Box 7, Pietermaritzburg, Natal.
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.
1888. ‡KNOTT, Professor CARGILL G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert, J.P. Sunnybank, Wilmslow, Cheshire.
1887. *Knott, John F. St. Martin's, Hooton, near Chester.
1906. *Knowles, Arthur J., B.A., M.Inst.C.E. Turf Club, 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.
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.
1903. *Lafontaine, Rev. H. C. de. 49 Albert-court, Kensington Gore, S.W.
1885. *Laing, J. Gerard. 3 Paper-buildings, Temple, E.C.

Year of Election.

1904. ‡Lake, Philip. St. John's College, Cambridge.
1904. ‡Lamb, C. G. Ely Villa, Glisson-road, Cambridge.
1889. *Lamb, Edmund, M.A., M.P. 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, 1904-07), Professor of Physiology in the University of Cambridge. Trinity College, Cambridge.
1865. ‡Lankester, Sir E. Ray, K.C.B., M.A., LL.D., D.Sc., F.R.S. (President, 1906; Pres. D, 1883; Council, 1889-90, 1894-95, 1900-02.) 29 Thurloe-place, 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.
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 I. Victoria and Albert Museum, London, S.W.
1870. *Latham, Baldwin, M.Inst.C.E., F.G.S. Parliament-mansions, 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.
1907. *Laurie, Robert Douglas. 16 James-street, Birkenhead.
1870. *Law, Channell. Ilsham Dene, Torquay.
1905. §Lawrence, Miss M. Roedean School, near Brighton.
1908. §Lawson, H. S., B.A. Westfield, Bath.
1908. §Lawson, William, LL.D. 27 Upper Fitzwilliam-street, Dublin.
1888. §Layard, Miss Nina F., F.L.S. Rookwood, Fonnereau-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.

Year of Election.

1895. *Ledger, Rev. Edmund. Protea, Doods-road, Reigate.
1907. §Lee, Mrs. Barton. 37 Derby-road, Heaton Moor, Stockport.
1896. §Lee, Rev. H. J. Barton. The Limes, Derby-road, Heaton Moor, Stockport.
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 Dr. Norris Wolfenden, 76 Wimpole-street, W.
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.
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.
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. *Lempfert, R. G. K., M.A. Meteorological Office, 63 Victoria-street, S.W.
1902. ‡Lennox, R. N. Rosebank, Hammersmith, W.
1908. §Lentaigne, John. 42 Merrion-square, Dublin.
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. *LEWES, 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, Newtown, Montgomeryshire.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.
1903. ‡Lewkowitsch, Dr. J. 71 Priory-road, N.W.

Year of Election.

1906. §Liddiard, James Edward, F.R.G.S. Rodborough Grange, Bournemouth.
1908. §Lilly, W. E., M.A., Sc.D. 39 Trinity College, Dublin.
1904. ‡Link, Charles W. 14 Chichester-road, Croydon.
1898. §Lippincott, R. C. Cann. Over Court, 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.) 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. United University Club, Suffolk-street, Pall Mall, 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.
1854. *LOBLEY, J. LOGAN, F.G.S., F.R.G.S. 36 Palace-street, Buckingham Gate, S.W.
1892. ‡LOCH, C. S., D.C.L. 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., D.Sc., 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.
1875. *LODGE, Sir OLIVER J., D.Sc., LL.D., F.R.S. (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.
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. Ridgelands, 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. Ridgelands, Wimbledon, S.W.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, S.W.
1899. *Longstaff, Tom G., M.A., M.D. Ridgelands, Wimbledon, S.W.
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.I.C. Savage Club, W.C.
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. (Pres. A, 1907), 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.

Year of Election.

1905. ‡Loveday, Professor T. South African College, Cape Town.
1908. §Low, Alexander, M.A., M.B. Marischal College, Aberdeen.
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.
1898. §Luxmoore, Dr. C. M. Central Technical Schools, Truro.
1903. ‡Lyddon, Ernest H. Lisvane, near Cardiff.
1884. ‡Lyman, H. H. 384 St. Paul-street, Montreal, Canada.
1907. *Lyons, Captain Henry George, R.E., D.Sc., F.R.S., Director-General of the Survey Department, Egypt. Gezira Gardens, Cairo, Egypt.
1908. §Lyster, George H. 34 Dawson-street, Dublin.
1908. §Lyster, Thomas W., M.A. National Library of Ireland, Kildare-street, Dublin.

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, Sir Donald, K.C.B., M.A., M.D., LL.D., B.Sc., Principal of the University of Glasgow.
1904. ‡Macalister, Miss M. A. M. Torrisdale, Cambridge.
1908. §Macallan, J., F.I.C., F.R.S.E. 3 Rutland-terrace, Clontarf, Co. Dublin.
1896. ‡Macallum, Professor A. B., Ph.D., D.Sc., 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., D.Sc., F.R.S. McGill University, Montreal, Canada.
1902. *Maccall, W. T., M.Sc. 223 Burrage-road, Plumstead.
1908. §McCarthy, Edward Valentine. Ardmanagh House, Glenbrook, Co. Cork.
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. §McClean, 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.

Year of Election.

1906. ‡McClure, Rev. E. 80 Eccleston-square, S.W.
1878. *M'Comas, Henry. Pembroke House, Pembroke-road, Dublin.
1908. §McCombie, Hamilton, M.A., Ph.D. The University, Birmingham.
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. Ramsay, M.P. 3 Lincoln's Inn-fields, W.C.
1890. *MacDonald, Mrs. J. Ramsay. 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.
1908. §McEwen, Walter, J. P. Flowerbank, Newton Stewart, Scotland.
1897. ‡McEwen, William C. 9 South Charlotte-street, Edinburgh.
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. 8 Matheson-road, Kensington, W.
1908. §McGrath, Joseph, LL.D. (Local Sec. 1908.) Royal University of Ireland, Dublin.
1906. §Macgregor, D. H., M.A. Trinity College, Cambridge.
1908. §MacGregor, Charles. Training Centre, Charlotte-street, Aberdeen.
1884. *MacGregor, James Gordon, M.A., D.Sc., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh.
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.
1908. §McKay, William, J.P. Clifford-chambers, York.
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. Maxieburn, Stonehaven, N.B.
1905. ‡McKenzie, A. R. P.O. Box 214, Cape Town.
1907. §McKenzie, Alexander, M.A., D.Sc., Ph.D. Birkbeck College, Bream's-buildings, Chancery-lane, E.C.
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. Netherby, Manse-road, Motherwell, N.B.
1872. *Mackey, J. A. United University Club, Pall Mall East, S.W.
1901. ‡Mackie, William, M.D. 13 North-street, Elgin.

Year of Election.

1887. ‡MACKINDER, H. J., M.A., F.R.G.S. (Pres. E, 1895; Council, 1904–1905.) London School of Economics, Clare Market, W.C.
1908. §MacKinnon, Mrs. Donald. Speldhurst Rectory, Tunbridge Wells.
1885. *M'LAREN, 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.
1901. ‡Maclaren, J. Malcolm. Royal Colonial Institute, Northumberland Avenue, W.C.
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. Beaconscroft, Chiddingfold, Godalming.
1908. §McLennan, J. C. The University, Toronto, Canada.
1868. §McLEOD, HERBERT, F.R.S. (Pres. B, 1892; Council, 1885–90.) 37 Montague-road, Richmond, Surrey.
1883. ‡MACMAHON, Major PERCY A., R.A., D.Sc., F.R.S. (GENERAL SECRETARY, 1902– ; Pres. A, 1901; Council, 1898–1902.) 27 Evelyn-mansions, Carlisle-place, 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.
1907. §Macrosty, Henry W. 29 Hervey-road, Blackheath, S.E.
1906. ‡Macturk, G. W. B. 15 Bowlalley-lane, Hull.
1908. §McVittie, R. B., M.D. 62 Fitzwilliam-square North, Dublin.
1908. §McWalter, J. C., M.D., M.A. 19 North Earl-street, Dublin.
1902. ‡McWeeney, E. J., M.D. 84 St. Stephen's-green, Dublin.
1902. ‡McWhirter, William. 9 Walworth-terrace, Glasgow.
1908. §MADDEN, Rt. Hon. Mr. Justice. Nutley, Booterstown, Dublin.
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., B.A., M.P. (Pres. L, 1907). 16 Gloucester-terrace, Hyde Park, W.
1908. *Magson, Egbert H. 67 Pepys-road, Cottenham Park, Wimbledon, S.W.
1902. ‡*Mahon, J. L. 2 May-street, Drumcondra, Dublin.*
1907. *Mair, David. Civil Service Commission, Burlington-gardens, W.
1908. §Mair, William, F.C.S. 7 Comiston-road, Edinburgh.
1908. §Makower, W. The University, Manchester.
1857. ‡MALLET, JOHN WILLIAM, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1905. §Maltby, Lieutenant G. R., R.N. 54 St. George's-square, S.W.
1897. ‡MANCE, Sir H. C. Old Woodbury, Sandy, Bedfordshire.
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.

Year of Election.

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.
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.) Balliol Croft, Madingley-road, Cambridge.
1904. ‡Marshall, F. H. A. University of Edinburgh.
1905. §Marshall, G. A. K. 6 Chester-place, Hyde Park-square, W.
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. Imperial Hotel, Malvern.
1907. §Marston, Robert. 14 Ashleigh-road, Leicester.
1899. §Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.
1891. *Martin, Edward P., J.P. The Hill, Abergavenny, Monmouthshire.
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.
1905. ‡Marwick, J. S. P.O. Box 1166, Johannesburg.
1905. ‡Marx, Mrs. Charles. Shabana, Robinson-street, Belgravia, South Africa.
1907. ‡Masefield, J. R. B., M.A. Rosehill, Cheadle, Staffordshire.
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, Manchester.
1908. §Matheson, Sir R. E., LL.D. Charlemont House, Rutland-square, Dublin.
1905. ‡Mathew, Alfred Harfield. P.O. Box 242, Cape Town.
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. University College, Gower-street, W.C.
1884. *Maybury, A. C., D.Sc. 411 Fulham-road, S.W.

Year of Election.

1905. §Maylard, A. Ernest. 10 Blythswood-square, Glasgow.
1905. ‡Maylard, Mrs. 10 Blythswood-square, Glasgow.
1878. *Mayne, Thomas. 19 Lord Edward-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 Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1908. §Meldrum, A. N., D.Sc. Chemical Department, The University, Manchester.
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.*
1905. §Meredith, H. O. Dunwood House, Withington, Manchester.
1908. §Meredith, Sir James Creed, LL.D. Royal University of Ireland, Dublin.
1879. ‡Merivale, John Herman, M.A. (Local Sec. 1889.) Togston Hall, Acklington.
1899. *Merrett, William H., F.I.C. Hatherley, Grosvenor-road, Wallington, 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., D.Sc., F.R.S., F.L.S., F.G.S. (Pres. D, 1897; Pres. L, 1908; Local Sec. 1890.) Norton Way North, Letchworth.
1903. *Mickletbwait, Miss Frances M. G. Penhein, Chepstow, Monmouth.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Bishop's House, Middlesbrough.
1904. ‡Middleton, T. H., M.A. South House, Barton-road, Cambridge.
1894. *Miers, H. A., M.A., F.R.S., F.G.S. (Pres. C, 1905), Principal of the University of London. 23 Wetherby-gardens, S.W.
1885. §Mill, Hugh Robert, D.Sc., LL.D., F.R.S.E., F.R.G.S. (Pres. E, 1901.) 62 Camden-square, N.W.
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. Andrew's-street, Cambridge.
1908. §Mills, Miss E. A. Nurney, Glenagarey, Co. Dublin.
1868. *Mills, Edmund J., D.Sc., F.R.S., F.C.S. 64 Twyford-avenue, West Acton, W.
1908. §Mills, Miss Gertrude Isabel. Nurney, Glenagarey, Co. Dublin.

Year of
lection.

1908. §Mills, John Arthur, M.B. Durham County Asylum, Winterton, Ferryhill.
1908. §Mills, W. H., M.Inst.C.E. Nurney, Glenagarey, Co. Dublin.
1902. ‡Mills, W. Sloan, M.A. Vine Cottage, Donaghmore, Newry.
1907. ‡Milne, A., M.A. University School, Hastings.
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.
1908. §Milroy, T. H., M.D., Dunville Professor of Physiology in Queen's College, Belfast.
1907. §Milton, J. H., F.G.S. Harrison House, Crosby, Liverpool.
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, Transvaal.
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.
1908. §Mitchell, W. M. 2 St. Stephen's Green, Dublin.
1905. ‡Mitter, M. Care of J. Speak, Esq., The Grange, Kirton, near Boston.
1895. *Moat, William, M.A. Johnson Hall, Eccleshall, Staffordshire.
1908. §Moffat, C. B. 36 Hardwicke-street, Dublin.
1905. §Moir, James, D.Sc. Mines Department, Johannesburg.
1905. ‡Moir, Dr. W. Ironside. Care of Dr. McAulay, Cleveland, Transvaal.
1905. §Molengraaff, Professor G. A. F. The Technical University of Delft, The Hague.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1908. §Molloy, W. R. J., J.P., M.R.I.A. 78 Kenilworth-square, Rathgar, Co. Dublin.
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.
1905. ‡*Moore, Charles Elliott. P.O. Box 5382, Johannesburg.*
1908. *Moore, F. W. Royal Botanic Gardens, Glasnevin, Dublin.
1894. §Moore, Harold E. Oaklands, The Avenue, Beckenham, Kent.
1908. §Moore, Sir John W., M.D. 40 Fitzwilliam-square West, Dublin.
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. Carlton Buildings, Parliament-street, Cape Town.
1901. *Moreno, Francisco P. Paraná 915, Buenos Aires.
1905. *Morgan, Miss Annie. Friedrichstrasse No. 2, Vienna.
1895. ‡MORGAN, C. LLOYD, F.R.S., F.G.S., Principal of University College, Bristol.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, South Kensington, S.W.
1896. ‡*Morgan, George. 21 Upper Parliament-street, Liverpool.*
1902. ‡MORGAN, GILBERT T., D.Sc., F.I.C. Royal College of Science, S.W.

Year of Election.

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.
1908. §Morris, E. A. Montmorency, M.A., M.R.I.A. Winton House, Cabra, Co. Dublin.
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.
1907. ‡Morris, Colonel Sir W. G., K.C.M.G. Care of Messrs. Cox & Co., 16 Charing Cross, W.C.
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.
1908. §Moss, Dr. C. E. Botany School, Cambridge.
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. 15 Grange-avenue, Harton, near 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., B.A., F.G.S. Geological Survey Office, 33 George-square, Edinburgh.
1902. §Muir, Arthur H. 2 Wellington-place, Belfast.
1907. *Muir, Professor James. 189 Renfrew-street, Glasgow.
1874. ‡MUIR, M. M. PATTISON, M.A. Gonville and Caius College, Cambridge.
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., F.R.S.E. Markham's-chambers, St. George's-street, Cape Town.
1876. *Muirhead, Robert Franklin, B.A., D.Sc. 64 Great George-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.
1908. §MULLIGAN, JOHN. (Local Sec. 1908.) Greinan, Adelaide-road, Kingstown, Co. Dublin.
1904. §Mullinger, J. Bass, M.A. 1 Bene't-place, 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.

Year of Election.

1890. ‡Murphy, A. J. Springfield Mount, Leeds.
1908. §Murphy, Leonard. 156 Richmond-road, Dublin.
1884. §Murphy, Patrick. Marcus-square, Newry, Ireland.
1908. §Murphy, William M., J.P. Dartry, Dublin.
1905. ‡Murray, Charles F. K., M.D. Kenilworth House, Kenilworth, Cape Colony.
1905. ‡Murray, Dr. F. Londinium, London-road, Sea Point, Cape Town.
1891. ‡Murray, G. R. M., F.R.S., F.R.S.E., F.L.S. 8 Kerrison-road, Ealing, W.
1905. §Murray, Sir J. A. H., LL.D., Litt.D. Sunnyside, Oxford.
1905. §Murray, Lady. 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.) Challenger Lodge, Wardie, Edinburgh.
1903. §Murray, Colonel 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., Professor of Greek in the University of Liverpool. 26 Abercromby-square, Liverpool.

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.
1908. §Nally, T. H. Temple Hill, Terenure, Co. Dublin.
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, M.A. Grange Court, 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.
1892. ‡Newton, E. T., F.R.S., F.G.S. Florence House, Willow Bridge-road, Canonbury, N.
1908. §Nicholls, W. A. 11 Vernham-road, Plumstead, Kent.
1908. §Nichols, Albert Russell. 30 Grosvenor-square, Rathmines, Co. Dublin.
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.
1908. §Nicholson, J. W. Trinity College, Cambridge.
1908. §Nixon, Sir Christopher, Bart., M.D., LL.D., D.L. 2 Merrion-square, Dublin.
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.

Year of Election.

1908. §Norman, Conolly, M.D. St. Dymphna's, North Circular-road, Dublin.
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.
1908. §Nutting, Sir John, Bart. St. Helen's, Co. Dublin.

1898. *O'Brien, Neville Forth. Fryth, Pyrford, Surrey.
1908. §O'Carroll, Joseph, M.D. 43 Merrion-square East, Dublin.
1883. ‡Odgers, William Blake, M.A., LL.D., K.C. 15 Old-square, Lincoln's Inn, W.C.
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.
1908. §O'Farrell, Thomas A. 30 Lansdowne-road, Dublin.
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, F.R.A.S. Overley, Langham-road, Bowdon, Cheshire.
1908. §Oldham, Charles Hubert, B.A., B.L. 44 Upper Leeson-street, Dublin.
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.
1889. ‡Oliver, Professor Sir Thomas, M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., D.Sc., 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.
1908. §O'Neill, Rev. G., M.A. University College, St. Stephen's Green, Dublin.
1902. ‡O'Neill, Henry, M.D. 6 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.
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.
1908. *Orr, William. Dungarvan, Co. Waterford.
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.

Year of Election.

1901. ‡Osborne, W. A., D.Sc. University College, W.C.
1908. §O'Shaughnessy, T. L. 64 Fitzwilliam-square, Dublin.
1887. ‡O'Shea, L. T., B.Sc. University College, Sheffield.
1865. *Osler, Henry F. Coppy-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.

1908. §Pack-Beresford, Denis, M.R.I.A. Fenagh House, Bagenalstown, Ireland.
1906. §Page, Carl D. Wyoming House, Aylesbury, Bucks.
1903. *Page, Miss Ellen Iva. Turret House, Felpham, Sussex.
1870. *PALGRAVE, ROBERT HARRY INGLIS, F.R.S., F.S.S. (Pres. F, 1883.) Henstead Hall, Wrentham, Suffolk.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1878. *Palmer, Joseph Edward. Royal Societies Club, St. James's-street, S.W.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
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.
1891. ‡PARKER, WILLIAM NEWTON, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1905. *Parkes, Tom E. P.O. Box 4580, Johannesburg.
1899. *Parkin, John. Blaithwaite, Carlisle.
1905. *Parkin, Thomas. Blaithwaite, Carlisle.
1906. §Parkin, Thomas, M.A., F.Z.S., F.R.G.S. Fairseat, High Wickham, Hastings.
1879. *Parkin, William. The Mount, Sheffield.
1903. §Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo, near Liverpool.
1908. §Parry, W. K., M.Inst.C.E. 6 Charlemont-terrace, Kingstown, Dublin.
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.
1908. §Paterson, M., LL.D. 7 Halton-place, Edinburgh.
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.
1908. §Patten, C. J., M.A., M.D., Sc.D. The University, Sheffield.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.

Year of Election.

1879. *Patzer, 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. Standard Iron Works, Colchester.
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, Yeovil.
1876. ‡Peace, G. H., M.Inst.C.E. Monton Grange, Eccles, near Manchester.
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., C.M.G. Hillsborough, Heath-road, Petersfield, Hampshire.
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.*
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, Lord, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, Ph.D., F.R.S.E., Professor of Natural Philosophy in University College, Dundee.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1878. *Peck, 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.
1908. §Percival, Professor John, M.A. University College, Reading.
1905. ‡Péringuey, L., D.Sc., 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.
1884. ‡Perkin, William Henry, LL.D., Ph.D., F.R.S., F.R.S.E. (Pres. B, 1900; Council, 1901-07), 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.

Year of Election.

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., M.Sc., F.R.S. The University, Manchester.
1901. ‡Pethybridge, G. H. Royal College of Science, 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.
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., F.R.S.E. 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.
1890. ‡Phillips, R. W., M.A., D.Sc., F.L.S., Professor of Botany in University College, Bangor. 2 Snowdon-villas, Bangor.
1905. ‡Phillp, 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.
1907. §Pickles, A. R., M.A. Todmorden-road, Burnley.
1888. *Pidgeon, W. R. Lynsted Lodge, St. Edmund's-terrace, Regent's Park, N.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.
1908. *Pio, Professor D. A. 6a Short-street, Cambridge.
1908. §Pirrie, The Right Hon. Lord, LL.D., M.Inst.C.E. Downshire House, Belgrave-square, S.W.
1893. *Pitt, Walter, M.Inst.C.E. Lansdown Grove Lodge, Bath.
1908. §Pixell, Miss Helen L. M. St. Faith's Vicarage, Stoke Newington, N.
1900. *Platts, Walter. Fairmount, Bingley.
1898. §Plummer, W. E., M.A., F.R.A.S. The Observatory, Bidston, Birkenhead.
1908. §Plunkett, Count G. N. National Museum of Science and Art, Dublin.
1908. §Plunkett, Colonel G. T., C.B. Belvedere Lodge, Wimbledon, S.W.
1907. *Plunkett, Right Hon. Sir Horace, K.C.V.O., M.A., F.R.S. Kilteragh, Foxrock, Co. Dublin.
1900 *Pocklington, H. Cabourn, M.A., D.Sc., F.R.S. 11 Regent's Park-terrace, Leeds.
1904. ‡Pollard, William. 12 Aberdare-gardens, South Hampstead, N.W.
1896. *Pollex, Albert. Tenby House, Egerton Park, Rockferry.
1908. §Pollok, James H., D.Sc. 6 St. James's-terrace, Clonshea, Dublin.

Year of Election.

1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1906. *Pontifex, Miss Catherine E. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1907. §Pope, Alfred, F.S.A. South Court, Dorchester.
1900. *Pope, W. J., F.R.S., Professor of Chemistry in the University of Cambridge.
1907. *Poppleton, Mrs. A. G. 12 Hyde Park-gate, S.W.
1892. ‡Popplewell, W. C., M.Sc., Assoc.M.Inst.C.E. Bowden-lane, Marple, 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. 13 Highbury, Newcastle-upon-Tyne.
1906. ‡Potter-Kirby, Alderman George. Clifton Lawn, York.
1907. ‡Potts, F. A. University Museum of Zoology, Cambridge.
1908. *Potts, George, Ph.D., M.Sc. Grey University College, Bloemfontein, South Africa.
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.
1908. §Praeger, R. Lloyd, B.A., M.R.I.A. Lisnamae, Rathgar, Dublin.
1907. *Prain, Lieut.-Col. David, C.I.E., M.B., F.R.S. (Council, 1907–). Royal Gardens, Kew.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1906. §Pratt, Miss Edith 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.
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.

Year of Election.

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. Charlton, Headington, Oxford.
1908. §Priestley, J. H. University College, Bristol.
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.
1884. *Proudfoot, Alexander, M.D. 100 State-street, Chicago, U.S.A.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1907. §Pryce, George Arthur. Care of Philip Harris & Co., Limited, 144 Edmund-street, Birmingham.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1871. *Puckle, Rev. T. J. Chestnut House, Huntingdon-road, Cambridge.
1867. *Pullar, Sir Robert, M.P., F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1903. §Pullen-Burry, Miss. 28 Fairholme-road, West Kensington, W.
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 Perceval, 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. 32 Queen Victoria-street, E.C.
1883. ‡Pye-Smith, Mrs. 32 Queen Victoria-street, E.C.
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.

1893. ‡Quick, James. 36 Kingsworth-gardens, Folkestone.
1906. *Quiggin, Mrs. A. Hingston. 88 Hartington-grove, Cambridge.

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.
1893. *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.
1908. §Rambaut, Mrs. Radcliffe Observatory, Oxford.

Year of Election.

1876. *RAMSAY, Sir WILLIAM, K.C.B., Ph.D., D.Sc., 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.
1907. §Rankine, A. O. 21 Drayton-road, West Ealing, 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.
1889. ‡Rapkin, J. B. Thrale Hall, Streatham, S.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.
1908. *Raworth, Alexander. Fairholm, Uppingham-road, Leicester.
1905. ‡Rawson, Colonel Herbert E., R.E. Army Headquarters, Pretoria.
1868. *RAYLEIGH, The Right Hon. Lord, O.M., M.A., D.C.L., LL.D., F.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. Elm Lodge, Queen's-road, Teddington, Middlesex.
1907. §Rea, Carleton, B.C.L. 34 Foregate-street, Worcester.
1896. *READ, CHARLES H., LL.D., 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. Staffield Hall, Kirkoswald, R.S.O., Cumberland.
1852. *REDFERN, Professor PETER, M.D. (Pres. D, 1874.) Templepatrick House, Donaghadee, Co. Down.
1890. *Redwood, Sir Boverton, F.R.S.E., F.C.S. Wadham Lodge, Wadham-gardens, N.W.
1908. §Reed, Sir Andrew, K.C.B., C.V.O., LL.D. 23 Fitzwilliam-square, Dublin.
1905. §Reed, J. Howard, F.R.G.S. 16 St. Mary's Parsonage, Manchester.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. Dunscar, 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, Sir 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. 30 Welbeck-street, W.
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.
1892. ‡REID, E. WAYMOUTH, B.A., M.B., F.R.S., Professor of Physiology in University College, Dundee.
1908. §REID, GEORGE ARCHDALL, M.B., C.M., F.R.S.E. 9 Victoria-road South, Southsea.

Year of Election.

1901. *Reid, Hugh. Belmont, Springburn, Glasgow.
1901. ‡Reid, John. 7 Park-terrace, Glasgow.
1904. ‡Reid, P. J. Moor Cottage, Nunthorpe, R.S.O., Yorkshire.
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, S.W.
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, Billinghurst, 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. 271 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. 8 Darnley-road, Notting Hill, 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., M.A., Professor of Geology and Zoology in University College, Bristol.
1907. §Reynolds, W. Birstall Holt, near Leicester.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1899. *RHYS, Professor Sir 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, M.A. Granville School, Granville-road, Leicester.
1906. ‡Richards, Rev. A. W. 12 Bootham-terrace, York.
1869. *Richardson, Charles. 3 Cholmley-villas, Long Ditton, Surrey.
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, Professor Owen Willans. 25 Bank-street, Princetown, N.J., U.S.A.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. §Riches, T. Hurry. 8 Park-grove, Cardiff.
1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-street, S.W.
1902. §RIDGEWAY, WILLIAM, M.A., D.Litt., F.B.A. (Pres. H, 1908), Professor of Archæology 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, I.S.O., M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.

Year of Election.

1860. *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.
1905. ‡Ritchie, Professor W., M.A. South African College, Cape Town.
1903. *Rivers, W. H. R., M.D., F.R.S. St. John's College, Cambridge.
1908. *Roaf, Herbert E., M.D. Physiological Department, The University, Liverpool.
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. University of London, South Kensington, S.W.
1896. ‡Roberts, Thomas J. Ingleside, Park-road, Huyton, near Liverpool.
1904. *Robertson, Miss Agnes, D.Sc. 9 Elsworthy-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. Duncan's-chambers, Shortmarket-street, 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.
1908. *Robinson, John Gorges. Cragdale, Settle, Yorkshire.
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.
1908. §Robinson, Robert. Field House, Chesterfield.
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.
1907. ‡Roechling, H. Alfred, M.Inst.C.E. 39 Victoria-street, S.W.
1908. §Rogers, A. G. L. Board of Agriculture and Fisheries, 8 Whitehall-place, S.W.
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.

Year of Election.

1907. ‡Rogers, John D. 85 St. George's-square, S.W.
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. Lamorva, Falmouth.
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.
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, Wimbledon, 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., M.A. Willenhall, Staffordshire.
1905. ‡Rosen, Jacob. 1 Hopkins-street, Yeoville, Transvaal.
1905. ‡Rosen, Julius. Clifton Grange, Jarvie-street, Jeppestown, Transvaal.
1900. ‡Rosenhain, Walter, B.A. Park View, Park-road, Teddington.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1908. §Ross, Sir John, of Bladensburg, K.C.B. Rostrevor House, Rostrevor, Co. Down.
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. The University, Liverpool.
1891. *Roth, H. Ling. Briarfield, Shibden, Halifax, Yorkshire.
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.
1883. ‡Rowan, Frederick John. 5 West Regent-street, Glasgow.
1903. *Rowe, Arthur W., M.B., F.G.S. 2 Price's-avenue, Margate.
1890. ‡Rowley, Walter, M.Inst.C.E., F.S.A. Alderhill, Meanwood, Leeds.
1906. §Rowntree, B. Seebohm. The Homestead, Clifton, York.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1875. *Rücker, Sir A. W., M.A., D.Sc., F.R.S. (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. Ethel Villa, Tatsfield, Westerham.
1901. *Rudorf, C. C. G., Ph.D., B.Sc. Ivor, Cranley-gardens, Muswell Hill, 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. 3 Fenwick-street, Liverpool.

Year of Election.

1904. ‡Russell, E. J., D.Sc., Rothamsted Experimental Station, Harpenden, Herts.
1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
Russell, John. 39 Mountjoy-square, Dublin.
1883. *Russell, J. W. 28 Staverton-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Dover-street, W.
1908. §Russell, Robert. Arduagremia, Haddon-road, Dublin.
1908. §Russell, Right Hon. T. W., M.P. Olney, Terenure, Co. Dublin.
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.
1907. §Rutherford, Ernest, M.A., D.Sc., F.R.S., Professor of Physics in the University of Manchester.
1908. §Ryan, Hugh, D.Sc. Omdurman, Orwell Park, Rathgar, Dublin.
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.
1871. ‡Sadler, Samuel Champernowne. Church House, Westminster, S.W.
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.
1907. *Sand, Dr. Henry J. S. University College, Nottingham.
1907. §Sandars, Miss Cora B. Parkholme, Elm Park-gardens, S.W.
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., M.Inst.C.E. Palace-chambers, 9 Bridge-street, S.W.
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.
1907. §Sargent, H. C. Ambergate, near Derby.
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. 35 Upper 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.

Year of Election.

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, National Museum, 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.
1908. §Schrödter, Dr. E. 3–5 Jacobistrasse, Düsseldorf, Germany.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S. (Pres. A, 1892; Council, 1887–93.) Kent House, Victoria Park, Manchester.
1905. ‡Sclander, J. E. P.O. Box 465, Cape Town.
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., Pres.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), Professor of Zoology and Comparative Anatomy in the University of Cambridge. 4 Cranmer-road, Cambridge.
1905. ‡Sedgwick, C. F. Strand-street, Cape Town.
1906. *See, T. J. J., A.M., Ph.D., F.R.A.S., Professor of Mathematics, U.S. Navy. 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.
1907. §Seligman, Dr. C. G. 15 York-terrace, Regent's Park, N.W.
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.

Year of Election.

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, 1901-07; 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, E. 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. ‡SHAFTESBURY, The Right Hon. the Earl of, D.L. Belfast Castle, Belfast.
1901. *Shakespear, Mrs. G. A. 21 Woodland-road, Northfield, Worcestershire.
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. ‡Sharples, George. 181 Great Cheetham-street West, Higher Broughton, Manchester.
1889. *Shaw, Mrs. M. S., B.Sc. Brookhayes, Exmouth.
1883. *SHAW, W. N., M.A., Sc.D., F.R.S. (Pres. A, 1908; Council, 1895-1900, 1901-07.) 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.
1900. §Sheppard, Thomas, F.G.S. The Municipal Museum, Hull.
1908. §Sheppard, W. F., Sc.D., LL.M. Board of Education, Whitehall, S.W.
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., D.Sc., F.R.S. (Pres. I, 1904; Council, 1907-), 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.
1908. *Shickle, Miss Mabel G. M. 9 Cavendish-crescent, 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., D.Sc., F.R.S. (Council, 1904- .) Christ's College, Cambridge.
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 Norwood, S.E.
1901. ‡Short, Peter M., B.Sc. 1 Holmdene-avenue, Herne Hill, S.E.
1908. §Shorter, Lewis B., B.Sc. 55 Campden Hill-road, W.
1904. *Shrubsall, F. C., M.A., M.D. 34 Lime-grove, Uxbridge-road, 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.

Year of Election.

1905. ‡Siemens, Mrs. A. 12 Queen Anne's-gate, S.W.
1903. *Silberrad, Dr. Oswald. Buckhurst Hill, Essex.
1871. *SIMPSON, Sir ALEXANDER R., M.D., Emeritus Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1908. §Simpson, J. J., M.A., B.Sc. Zoological Department, Marischal College, Aberdeen.
1901. *Simpson, Professor J. Y., M.A., D.Sc., F.R.S.E. 52 Queen-street, Edinburgh.
1907. §Simpson, Lieut.-Colonel R. J. S., C.M.G. 1 Amherst-avenue, Ealing, W.
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.
1907. *Sircar, Dr. Amrita Lal, L.M.S., F.C.S. 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.
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. Leonards-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. 48 Kedleston-road, 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, Dowanhill, Glasgow.
1902. §Smedley, Miss Ida. 11 Mecklenburgh-square, W.C.
1905. ‡Smith, Miss Adelaide. Huguenot College, Wellington, Cape Colony.
1908 §Smith, Alfred. 30 Merrion-square, Dublin.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Chicago, Illinois, U.S.A.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1901. *Smith, Miss Annie Lorrain. 20 Talgarth-road, West Kensington, W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, S.W.
1873. ‡Smith, C. Sidney-Sussex 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 Observatory, Kodaikanal, South India.
1908 §Smith, E. Shrapnell. 7 Rosebery-avenue, E.C.
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., F.R.S. St. John's College, Cambridge.
1903. *Smith, H. B. Lees. 16 Park-terrace, Oxford.
1889. *Smith, Sir H. Llewellyn, K.C.B., B.A., B.Sc., F.S.S. Board of Trade, S.W.

Year of Election.

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. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1894. §Smith, T. Walrond. Care of Frank Henderson, Esq., Shirley, Station-road, Sidcup, Kent.
1908 §Smith, Walter G. 25 Merrion-square, Dublin.
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. (Pres. B, 1907; Local Sec. 1890), Professor of Chemistry in the University of Leeds.
1906. §Smurthwaite, Thomas E. 134 Mortimer-road, Kensal Rise, N.W.
1905. §Smuts, C. P.O. Box 1088, Johannesburg.
1908. §Smyly, Sir William J. 58 Merrion-square, Dublin.
1908 §Smyth, J. A., Ph.D., D.Sc. 15 The Poplars, Gosforth, Newcastle-on-Tyne.
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, Southport.
1905. ‡Soddy, F. The University, Glasgow.
1905. §Sollas, Miss I. B. J., B.Sc. 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. *Somervail, Alexander. The Museum, Torquay.
1900. *Somerville, W., D.Sc., F.L.S., Sibthorpian Professor of Rural Economy in the University of Oxford. 121 Banbury-road, Oxford.
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, Highbury, 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. 6 Middle New-street, Fetter-lane, E.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.

Year of Election.

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. 19 Cawdor-road, Fallowfield, 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.
1907. §Staynes, Frank. 36–38 Silver-street, Leicester.
1900. *Stead, J. E., F.R.S. Laboratory and Assay Office, Middlesbrough.
1881. ‡Stead, W. H. Beech-road, Reigate.
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.
1908 §Steele, Lawrence Edward, M.A., M.R.I.A. 18 Crosthwaite-park East, Kingstown, Co. Dublin.
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. Grianan, Glasnevin, Dublin.
1908 *Steven, Alfred Ingram, M.A., B.Sc. 54 Albert-drive, Pollokshields, Glasgow.
1906. §Stevens, Miss C. O. 11 Woodstock-road, Oxford.
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. 127 Isabella-street, Toronto, Canada.
1905. ‡Stewart, Charles. Meteorological Commission, Cape Town.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Junior Constitutional Club, Piccadilly, W.
1901. *Stewart, John Joseph, M.A., B.Sc. 2 Stow Park-crescent, Newport, Monmouthshire.
1901. *Stewart, Thomas. St. George's-chambers, Cape Town.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Victoria University, Manchester.
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.

Year of Election.

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 Chepstow-crescent, W.
1908 *Stoney, Miss Florence A., M.D. 46 Harley-street, 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 Chepstow-crescent, W.
1903. *Stopes, Miss Marie, Ph.D., D.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., F.G.S. P.O. Box 7, Pietermaritzburg, Natal.
1881. ‡STRAHAN, AUBREY, M.A., F.R.S., F.G.S. (Pres. C, 1904.) Geological Museum, Jermyn-street, S.W.
1905. ‡Strange, Harold F. P.O. Box 2527, Johannesburg.
1881. §STRANGWAYS, C. FOX, F.G.S. Kylemore, Hollycroft-avenue, West Hampstead, N.W.
1908 *Stratton, F. J. M., M.A. Gonville and Caius College, Cambridge.
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., M.D. 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. Gowan Lea, Ilkley.
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. Canon Edward A., M.A. The Precincts, Canterbury.
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, Birmingham.
1908. §Sutherland, Alexander. 25 Mount-street, Aberdeen.
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.
1908. §Swanzy, Sir Henry R., M.D. 23 Merrion-square, Dublin.
1882. *Swaythling, Lord. 12 Kensington Palace-gardens, W.
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.
1895. ‡Sykes, E. R., B.A. 3 Gray's Inn-place, W.C.

Year of Election.

1902. *Sykes, Miss Ella C. Elcombs, Lyndhurst, Hampshire.
1887. *Sykes, George, H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1906. *Sykes, Miss M. G. Royal Holloway College, Englefield Green, Surrey.
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.
1908. §Synnott, Nicholas J. Furness, Naas, Co. Kildare.

1896. ‡Tabor, J. M. Holmwood, Haringey 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. Grantchester, near Cambridge.
1883. *Tapscott, R. Lethbridge, F.R.A.S. 62 Croxteth-road, Liverpool.
1908. §Tarleton, Francis A., LL.D. 24 Upper Leeson-street, Dublin.
1861. *Tarratt, Henry W. 2c Oxford and Cambridge-mansions, Hyde Park, W.
1902. ‡Tate, Miss. Rantalard, Whitehouse, Belfast.
1901. ‡*Taylor, Benson. 22 Hayburn-crescent, Partick, Glasgow.*
1908. §Taylor, Rev. Campbell, M.A. United Free Manse, Wigtown, Scotland.
1887. ‡Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1898. ‡Taylor, Lieut.-Colonel G. L. Le M. 6 College-lawn, Cheltenham.
1881. *Taylor, H. A. 12 Melbury-road, Kensington, W.
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. 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., M.A. South Hylton Vicarage, Sunderland.
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.

Year of Election.

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 University 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. Pencerrig, Builth.
1903. *Thomas, Miss Ethel N., B.Sc. 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. Beatrice. Girton College, Cambridge.
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 University College, Dundee.
1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop.
1907. *Thompson, Edwin. 1 Croxteth-grove, Liverpool.
1883. *Thompson, Francis. Eversley, Haling Park-road, Croydon.
1904. *Thompson, G. R., B.Sc., Professor of Mining in the University of Leeds.
1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of National Bank of India, 17 Bishopsgate-street Within, E.C.
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. (Pres. G, 1907; Council, 1897-99), Principal and Professor of Physics in the City and Guilds of London Technical College, Leonard-street, Finsbury, E.C.
1883. *Thompson, T. H. Oldfield Lodge, Gray-road, Bowdon, Cheshire.
1896. *THOMPSON, W. H., M.D., D.Sc. (Local Sec. 1908), King's Professor of Institutes of Medicine (Physiology) in Trinity College, Dublin. 14 Hatch-street, Dublin.
1905. ‡*Thompson, William. Parkside, Doncaster-road, Rotherham.*
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, Sir J. J., M.A., Sc.D., D.Sc., F.R.S. (PRESIDENT ELECT; Pres. A, 1896; Council, 1893-95), Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1901. ‡Thomson, Dr. J. T. Kilpatrick. 148 Norfolk-street, Glasgow.

Year of Election.

1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1891. ‡Thomson, John. Westover, Mount Ephraim-road, Streatham, S.W.
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.
1906. §Thornely, Miss A. M. M. Oaklands, Langham-road, Bowdon, Cheshire.
1905. *Thornely, Miss L. R. Nunclose, Grassendale, Liverpool.
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., F.R.S. Victoria University, 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.
1899. §Threlfall, Richard, M.A., F.R.S. 30 George-road, Edgbaston, Birmingham.
1896. §Thrift, William Edward, M.A. (Local Sec. 1908), Professor of Natural and Experimental Philosophy in the University of Dublin. 80 Grosvenor-square, Rathmines, Dublin.
1904. §Thurston, Edgar. Government Museum, Madras.
1907. §Thwaites, R. E. 138 Kimberley-road, Leicester.
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.
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., B.Sc., F.I.C. 5 Chapel-street, Peterhead, N.B.
1907. §Todd, Professor J. L. MacDonald College, Quebec, Canada.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1905. ‡Tonkin, Samuel. Rosebank, near Cape Town.
1875. ‡Torr, Charles Hawley. 35 Burlington-road, Sherwood, Nottingham.
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.

Year of Election.

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.
1908. §Treen, Henry M. Wicken, Sohan, Cambridge.
1908. §Tremain, Miss Caroline P., B.A. Alexandra College, Dublin.
1887. *Trench-Gascoigne, Mrs. F. R. Lotherton Hall, Parlington, Aberford, Leeds.
1903. ‡Trenchard, Hugh. The Firs, Clay Hill, Enfield.
1908. §Tresilian, R. S. Cumnor, Eglington-road, Dublin.
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. 68 Harley-street, 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. Springfields, Tipland-road, Selly Hill, Birmingham.
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.
1907. §TUTTON, A. E. H., M.A., D.Sc., F.R.S. (Council, 1908– .) 41 Ladbroke-square, W.
1886. *Twigg, G. H. 667 Ludgate-hill, Birmingham.
1899. ‡Twisden, John R., M.A. 14 Gray's Inn-square, W.C.
1907. §Twyman, F. 75A Camden-road, N.W.
1865. §TYLOR, EDWARD BURNETT, D.C.L., LL.D., F.R.S. (Pres. H, 1884; Council, 1896–1902), Professor of Anthropology in the University 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.
1908. §Unwin, Ernest Ewart, M.Sc. Ackworth School, Ackworth, near Pontefract.

Year of Election.

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.
1908. §Valera, Edward de. University College, Blackrock, Dublin.
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.
1907. §Varley, W. Mansergh, M.A., D.Sc., Ph.D. 27 St. Hilary-terrace, Devonport.
1903. ‡Varwell, H. B. 2 Pennsylvania-park, Exeter.
1907. §Vaughan, Arthur, B.A., D.Sc., F.G.S. 9 Pembroke-vale, Clifton, Bristol.
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. 8 Marlborough-place, St. John's Wood, N.W.
1873. *Verney, Sir Edmund H., Bart., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1904. *Vernon, H. M., M.A., M.D. 22 Norham-road, Oxford.
1896. *Vernon, Thomas T. Shotwick Park, Chester.
1896. *Vernon, William. Shotwick Park, Chester.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Carlisle Lodge, Rickmansworth.
1906. *Vincent, J. H., M.A., D.Sc. L.C.C. Paddington Technical Institute, Saltram-crescent, W.
1899. *Vincent, Swale, M.D., D.Sc. (Local Sec. 1909), Professor of Physiology in the University 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. Sinn Fein, Shooter's Hill, S.E..
1904. §Volterra, Professor Vito. Regia Universita, Rome.

1904. §Wace, A. J. B. Pembroke College, Cambridge.
1902. ‡Waddell, Rev. C. H. The Vicarage, Saintfield.
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. Stricklandgate House, Kendal.
1894. ‡Walford, Edwin A., F.G.S. 21 West Bar, Banbury.
1882. *Walkden, Samuel, F.R.Met.S. The Cottage, Whitchurch, Tavistock.
1893. §Walker, Alfred O., F.L.S. Ulcombe-place, Maidstone, Kent.
1890. ‡Walker, A. Tannett. The Elms, Weetwood, Leeds.

Year of Election.

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.
1894. *WALKER, JAMES, M.A. 30 Norham-gardens, Oxford.
1906. §Walker, Dr. Jamieson. 37 Charnwood-street, Derby.
1907. ‡Walker, Philip F., F.R.G.S. 36 Prince's-gardens, S.W.
1908. *Walker, Robert. 3 Grand Parade, The Hoe, Plymouth.
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, O.M., 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. (Pres. I, 1907.) 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. *WALMISLEY, A. T., M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1908. §Walsh, John M. Pleona Park-avenue, Sidney-parade, Dublin.
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.
1874. ‡Ward, John, J.P., F.S.A. Beesfield, Farningham, Kent.
1858. ‡Wardle, Sir Thomas, F.G.S. St. Edward-street, Leek, Staffordshire.
1905. ‡Warlow, Dr. G. P. 15 Hamilton-square, 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.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. 2 Countess-road, Nuneaton.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.

Year of Election

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., M.Inst.C.E. Moorlands, Worcester.
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.
1879. *Watson, William Henry, F.C.S., F.G.S. Braystones House, Beckermet, Cumberland.
1901. §Watt, Harry Anderson, M.P. Ardenslate House, Hunter's Quay, Argyllshire.
1875. *Watts, John, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Canon Robert R. The Red House, Bemerton, Salisbury.
1873. *Watts, W. Marshall, D.Sc. Shirley, Venner-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. Kenmore, Wilmslow, Cheshire.
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.
1907. §Webb, Wilfred Mark. Odstock, Hanwell, W.
1891. ‡Webber, Thomas. 12 Southey-terrace, Wordsworth-avenue, Roath, Cardiff.
1908. §Wedderburn, Ernest Maclagan, F.R.S.E. 6 Luccoth-gardens, Edinburgh.
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.
1908. §Welland, Rev. C. N. Wood Park, Kingstown, Co. Dublin.
1881. §Wellcome, Henry S. Snow Hill-buildings, E.C.
1908. §Wellisch, E. M. 17 Park-street, Cambridge.
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. Escrick Park, Yorkshire.
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.

Year of Election.

1882. *Westlake, Ernest, F.G.S. Fordingbridge, Salisbury.
1900. ‡Wethey, E. R., M.A., F.R.G.S. 4 Cunliffe-villas, Manningham, Bradford.
1878. *Wheeler, W. H., M.Inst.C.E. 4 Hope-park, Bromley, Kent.
1888. §Whelen, John Leman. 23 Fairhazel-gardens, 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.; and Clarendon Lodge, St. John's-gardens, Holland Park, W.
1908. §White, Mrs. A. Silva. Clarendon Lodge, St. John's-gardens, Holland Park, 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. Municipal Science and Technical School, West Bromwich.
1907. *Whitley, E. Clovelly, Sefton Park, Liverpool.
1905. *Whitmee, H. B. P.O. Box 470, Durban, Natal.
1891. ‡Whitmell, Charles T., M.A., B.Sc. Invermay, Hyde Park, Leeds.
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.
1881. **Wigglesworth, Robert. Ashtead Lodge, Surrey.*
1889. *WILBERFORCE, L. R., M.A., Professor of Physics in the University of Liverpool.
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.

Year of Election.

1861. *Williams, Charles Theodore, M.V.O., M.A., M.D. 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. The Hurst, Branksome Park, Bournemouth.
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. ‡Willink, 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.
1908. §Wilson, Miss. Grove House, Paddock, Huddersfield.
1901. ‡Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
1886. ‡*Wilson, Alexander B. Holywood, Belfast.*
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. United Free Church Manse, North Queensferry.
1905. §Wilson, A. W. P.O. Box 24, Langlaagte, South Africa.
1907. §Wilson, A. W. 20 Westcott-street, Hull.
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, F.R.G.S. 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.
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.*
1908. §Wilson, Professor James, M.A., B.Sc. Cluny, Orwell Park, Dublin.
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.

Year of Election.

1901. *Wilson, Joseph. Hillside, Avon-road, Walthamstow, N.E.
1908. *Wilson, Malcolm, B.Sc. Royal College of Science, S.W.
1903. ‡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. Battlehillock, Kildrumny, Mossat, Aberdeenshire.
1907. §Wimperis, H. E. 28 Rossetti Garden-mansions, S.W.
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.
1875. *Wood, George William Rayner. Singleton Lodge, Manchester.
1908. §Wood, Henry J. 4 Elsworthy-road, N.W.
1878. ‡Wood, Sir H. Trueman, M.A. Royal 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., Professor of Agriculture in the University of Cambridge. Caius College, Cambridge.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.
1901. *Wood, William James, F.S.A. (Scot.) 266 George-street, Glasgow.
1899. *Woodcock, Mrs. E. M. Pahargoomiah Tea Association, Bagdoora P.O., *viâ* 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. University College, Gower-street, 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. The Lindens, St. Mary's-road, 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.) 13 Arundel-gardens, Notting Hill, W.
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.
1908. §Woolacott, David, D.Sc., F.G.S. 8 The Oaks West, Sunderland.
1890. *Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1908. §Worsdell, W. C. 27 Flanders-road, Chiswick, W.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1901. ‡Worth, J. T. Oakenrod Mount, Rochdale.

Year of Election.

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.
1908. *Worthington, James H., B.A., F.R.A.S. Wycombe Court, High Wycombe.
1906. ‡WRAGGE, R. H. VERNON. York.
1896. ‡Wrench, Edward M., M.V.O., F.R.C.S. Park Lodge, Baslow, Derbyshire.
1905. ‡Wrentmore, G. G. Marva, Silwood-road, Rondebosch, Cape Colony.
1906. ‡Wright, Sir A. E., M.D., D.Sc., F.R.S. 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. 79 Harvard-court, Honeybourne-road, N.W.
1901. *Young, John. 2 Montague-terrace, Kelvinside, Glasgow.
1905. ‡Young, Professor R. B. Transvaal Technical Institute, Johannesburg.
1885. ‡YOUNG, R. BRUCE, M.A., M.B. 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.
1907. *YOUNG, W. H., M.A., Sc.D., F.R.S. 44A Wilhelm-Weberstrasse, Göttingen, Germany.
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 E. van Beneden, D.C.L. 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 Chaîne, Toulouse, France.
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 Nazionale 181, Rome.
1889. W. H. Dall, Sc.D. United States Geological Survey, Washington, D.C., U.S.A.
1872. Dr. Yves Delage. Faculté des Sciences, La Sorbonne, Paris.
1901. 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.

894. 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 Détaille, 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.
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. 30 Langdon-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., D.Sc., 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.
1876. Dr. W. J. Janssen. Villa Polar, Massagno, Lugano, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy, Annapolis, Maryland, U.S.A
1887. Professor C. Julin. 153 rue de Fragnée, Liège.
1876. Dr. Giuseppe Jung. Bastions Vittoria 41, Milan.
1884. Baron 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.
1872. M. Georges Lemoine. 76 rue Notre Dame des Changes, Paris.
1901. Professor Philipp Lenard. Schlossstrasse 7, Heidelberg.

Year of Election.

1887. Professor A. Lieben. Molkerbastei 5, 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.
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.
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, Via S. Maria, Pisa, Italy.
1864. Dr. G. Neumayer. Deutsche Seewarte, Hamburg.
1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
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, Massachusetts, U.S.A.
1887. Professor Georg Quincke. Hauptstrasse 47, Friederichsbau, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich. Sonnenstrasse 7.
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
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, Hyde Park, Massachusetts, U.S.A.
1895. Professor Karl Runge. Goldgraben 20, Göttingen, Germany.
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.

Year of Election.

1881. Professor Dr. Rudolf Sturm. Weyderstrasse 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. Imperial Academy of Sciences, St. Petersburg.
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.
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 Irish Academy.
——, Royal Society.
Dundee, University College.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Royal Albert Memorial College Museum.
Glasgow, Royal Philosophical Society of.
——, 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.
——, Chemical Society.
——, Civil Engineers, Institution of.
——, Geological Society.
——, Geology, Museum of Practical.
——, Greenwich, Royal Observatory.
——, Guildhall, Library.
——, Institution of Mechanical Engineers.
——, King's College.
——, Linnean Society.
London, London Institution.
——, Meteorological Office.
——, Physical Society.
——, Royal Anthropological Institute.
——, 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 Society of Arts.
——, 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.
Bonn ....University Library.
Brussels ....Royal Academy of Sciences.
Charkow ....University Library.
Coimbra .....Meteorological Observatory.
Copenhagen...Royal Society of Sciences.
Dorpat, Russia University Library.
Dresden ....Royal Public Library.
Frankfort ...Natural History Society.
Geneva.......Natural History Society.
Göttingen ....University Library.
Grätz ....Naturwissenschaftlicher Verein.
Halle ....Leopoldinisch - Carolinische Akademie.
Harlem ......Société Hollandaise des Sciences.
Heidelberg....University Library.
Helsingfors ...University Library.
Jena ....University Library.
Kazan, Russia University Library.
Kiel ....Royal Observatory.
Kiev ....University Library.
Lausanne ....The University.
Leiden ....University Library.
Liège ....University Library.
Lisbon ....Academia Real des Sciences.
Milan ....The Institute.
Modena ......Royal Academy.
Moscow ......Society of Naturalists.
Moscow ......University Library.
Munich.......University Library.
Naples ....Royal Academy of Sciences.
Paris.........Association Française pour l'Avancement des Sciences.
—— ....Geographical Society
—— ....Geological Society.
—— ....Royal Academy of Sciences.
—— ....School of Mines.
Pultova ......Imperial Observatory.
Rome ....Accademia dei Lincei.
—— ....Collegio Romano.
—— ....Italian Geographical Society.
—— ....Italian Society of Sciences.
Roumania ..Roumanian Association for the Advancement of Science.
St. Petersburg.University Library.
—— ....Imperial Observatory.
Stockholm ...Royal Academy.
Turin ....Royal Academy of Sciences.
Upsala ......Royal Society of Science.
Utrecht ......University Library.
Vienna ......The Imperial Library.
—— ....Central Anstalt für Meteorologie und Erdmagnetismus.
Zurich........Naturforschende Gesellschaft.

ASIA.

Agra ....The College.
Bombay .....Elphinstone Institution.
—— ....Grant Medical College.
Calcutta .....Asiatic Society.
—— ....Hooghly College.
Calcutta .....Medical College.
—— ....Presidency College.
Ceylon ....The Museum, Colombo.
Madras ......The Observatory.
—— ....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.

Amherst......The Observatory.

Baltimore ....Johns Hopkins University.

Boston ......American Academy of Arts and Sciences.

—— ....Boston Society of Natural History.

California.....The University.

—— ......Lick Observatory.

—— ....Academy of Sciences.

Cambridge ...Harvard University Library.

Chicago ......American Medical Association.

—— ....Field Museum of Natural History.

Kingston .....Queen's University.

Manitoba ....Historical and Scientific Society

—— ....The University.

Massachusetts .Marine Biological Laboratory, Woods Holl.

Mexico ......Sociedad Científica 'Antonio Alzate.'

Missouri .....Botanical Garden.

Montreal .....Council of Arts and Manufactures.

—— ......McGill University.

New York ...American Society of Civil Engineers.

—— ....Academy of Sciences.

Ottawa.......Geological Survey of Canada.

Philadelphia ..American Philosophical Society.

—— ....Franklin Institute.

—— ....University of Pennsylvania.

Toronto .....The Observatory.

—— ....The Canadian Institute.

—— ....The University.

Washington...Bureau of Ethnology.

—— ....Smithsonian Institution.

—— ....The Naval Observatory.

—— ....United States Geological Survey of the Territories.

—— ....Library of Congress.

—— ....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.

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